Alaska Department of Transportation & Public Facilities
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Improving Passing Lane Safety and Efficiency for Alaska's Rural Non-divided Highways

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A series of experiments using a fixed-base driving simulator were conducted to examine the potential safety and operational benefits of several highway safety interventions for reducing collision risk. Our approach sought to go beyond typical mitigations of collision risk that use explicit behavioral interventions, such as enforcing lower speed limits (regulation) and public education (safety warnings). Instead, we examined whether semi-permanent alterations to the visual appearance of the unsafe zones might implicitly reduce risky driver behaviors by slowing traffic and inducing better passing decisions without drivers being consciously aware that their behavior is being affected.

Such implicit changes in behavior may be more efficient and long-lasting since they do not require conscious compliance from drivers nor engagement from law enforcement. Taken together, the results of our experiments clearly show that regulatory signs early in a passing zone that limit the speed of right-lane drivers relative to left-lane drivers offer the greatest opportunity for increasing the efficiency—and perhaps also the safety—of rural passing zones.</td></tr>
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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Executive Summary

Passing lanes in two-lane two-way rural highways provide motorists with the opportunity to pass slow moving vehicles, improving the level of service of the operations in these highways. Such passing maneuvers, however, can lead to a hazardous situation for the passing vehicle as well as for the opposing traffic. Several head-on fatal and severe injury crashes have occurred in passing lanes in Alaska either at merge points (where passing maneuvers have continued too far) or just downstream of passing lanes where demand to pass is high. Field observations have shown that, once entering the wider roads and high design quality of passing lanes, some vehicles, including large trucks and recreational vehicles, tend to increase speeds. Many motorists are observed to speed in the fast lane and pass at excessive speeds that could carry into the merge area increasing the risk of a fatal or a severe injury crash. Passing lane safety and efficiency can be significantly improved if the lead vehicles with varying speeds were induced to maintain a relatively slower speed allowing more vehicles to pass without excessive speeds or reckless weaving maneuvers.

Objectives. The goal of our study was to go beyond typical mitigations of collision risk that use explicit behavioral interventions, such as enforcing lower speed limits (regulation) and public education (safety warnings). Our aim was to examine whether semi-permanent alterations to the visual appearance of the unsafe zones might implicitly reduce risky driver behaviors by slowing traffic and inducing better passing decisions without drivers being consciously aware that their behavior is being affected.

Such implicit changes in behavior may be more efficient and long-lasting since they do not require conscious compliance from drivers nor engagement from law enforcement. Taken

together, the results of our experiments clearly show that regulatory signs early in a passing zone that limit the speed of right-lane drivers relative to left-lane drivers offer the greatest opportunity for increasing the efficiency—and perhaps also the safety—of rural passing zones.

Conclusions. Taken together, the results of our two experiments clearly show that regulatory signs early in a passing zone that limit the speed of right-lane drivers relative to left-lane drivers offer the greatest opportunity for increasing the efficiency—and perhaps also the safety—of rural passing zones. We found that regulatory signs imposing split speed limits between the lanes (65 mph-left, 55 mph-right) or limiting RVs and trucks to 55 mph along with advisories to allow others to pass, reliably increased the difference in speed between left- and right-lane drivers, which should allow more passes to occur within each passing zone. This increase in passing efficiency has the potential to reduce driver frustration and passing urgency, and may therefore significantly enhance the safety of rural highways.

In contrast, the passive speed reduction scenarios we tested (Chevrons, transverse lines, parallax, lane narrowing) were all far less effective in reducing speed of drivers in the right-hand lane. This result was surprising given that previous research on passive speed mitigations found significant reductions in speeds approaching roundabouts and freeway off-ramps. The difference in results could be due to any number of factors, but two hypotheses seem particularly important to test: a) right-lane drivers in our study may have been distracted by the need to monitor vehicles passing them and finding a gap to merge and may not have paid attention to the passive highway markings, and b) passive speed measures may only affect speed control in situations where a driver is already slowing down, rather than maintaining constant speed. Future research will be needed to determine why passive speed reduction appears to work for some highway applications but not for passing zones.

CHAPTER 1: INTRODUCTION

Overview

Passing lanes in two-lane two-way rural highways provide motorists with the opportunity to pass slow moving vehicles, improving the level of service of the operations in these highways. Such passing maneuvers, however, can lead to a hazardous situation for the passing vehicle as well as for the opposing traffic. Several head-on fatal and severe injury crashes have occurred in passing lanes in Alaska either at merge points (where passing maneuvers have continued too far) or just downstream of passing lanes where demand to pass is high. Field observations have shown that, due to the wider roads and high design quality of passing lanes, some vehicles, including large trucks and recreational vehicles, tend to increase speeds once entering passing lanes, leading most motorists to pass at excessive speeds that could carry into the merge area increasing the risk of a fatal or a severe injury crash. Passing lane safety and efficiency can be significantly improved if the lead vehicles with varying speeds were induced to maintain a relatively slower speed allowing more vehicles to pass without excessive speeds or reckless weaving maneuvers. In this study, we developed novel lane markings and signage based on a scientific understanding of human perception and decision making (i.e., human factors) and assessed the potential of these safety interventions for reducing speed and risky passing behavior by conducting a series of driving simulation experiments. This study does not address issues of regulation and law enforcement, but rather focuses on potential changes in driver behavior through the structural design of the highway, its signage and markings.

A series of experiments using the University of Idaho's National Advanced Driving Simulator (NADS) Minisim fixed-base driving simulator were conducted to examine the potential safety and operational benefits of several highway safety interventions for reducing collision risk. These safety interventions were aimed at inducing safer driver behaviors such as slowing in the right-hand lane while being passed to reduce incidences of last-second, high-speed passes. Our approach goes beyond typical mitigations of collision risk that use explicit behavioral interventions such as enforcing lower speed limits (regulation) and public education (safety warnings). These explicit enforcement interventions can be costly to implement and have limited impact on a sometimes uncooperative public who are in a hurry and whose decision making might be impaired by alcohol or fatigue.

Our aim is to examine whether semi-permanent alterations to the visual appearance of the unsafe zones might implicitly reduce risky driver behaviors by slowing traffic and inducing better passing decisions without drivers being consciously aware that their behavior is being affected. Such implicit changes in behavior may be more efficient and long-lasting since they do not require conscious compliance from drivers nor engagement from law enforcement. Rather, these safety interventions will be designed to passively engage drivers in safer passing behaviors by sub-consciously altering their perceptions of speed and distance.

A second issue addressed in this study is whether large vehicles that block the visibility of following traffic (e.g. trucks and recreational vehicles) increase a drivers' desire to pass, even when the large vehicle is traveling at an acceptable speed. Anecdotal observations suggests that the inability of drivers to see around large vehicles may increase the probability of risky passing behaviors. Our study specifically manipulates the size and visual characteristics of obstructing vehicles to assess this issue empirically.

Report Organization

This report is organized into five chapters. After the introduction, the general method employed in this research is described in chapter 2. The next two chapters describe two driver simulation experiments including each experiment's results and analysis of this data. The last chapter summarizes the overall conclusions we draw based on these two experiments and offer recommendations for further research.

CHAPTER 2: GENERAL METHOD

Aims

We conducted two experiments aimed at evaluating the efficacy of various passing zone scenarios on driving behavior. In each experiment, we tested a sample of participants driving a simulation of a two-lane rural highway through the Alaskan countryside with passing zones occurring intermittently. Our simulation method had two broad aims. First, we endeavored to immerse drivers in a simulation so as to produce natural driving behaviors. To this end, we developed a virtual environment describing a 50 mile driving loop through typical rural terrain (farms, forests, mountains) and instructed our participants to imagine they would be driving through the Alaskan countryside after a long recreational weekend and to drive with their "normal style and etiquette" (instructions are detailed in the procedure sections of each experiment).

Our second broad aim was to examine effects of the passing zone scenarios on the behavior of two types of drivers: those towing a recreational vehicle (RV) and those driving a sedan not towing a RV. Experiment 1 examined drivers towing a RV, while Experiment 2 examined sedan (non-towing) drivers. Different traffic scenarios were developed for these two categories of drivers and slightly different instructions were provided to implicitly induce the RV-towing drivers to use the right lane of passing zones to let vehicles pass and the non-towing drivers to use the left hand lane and attempt to pass slower traffic (see the procedure sections for each Experiment for details).

Figure 1: Advisory and Regulatory signs that preceded each passing zone.

Stimuli

Both experiments used almost identical stimuli. Participants drove a 50-mile track simulating a two-lane rural Alaskan highway with 10 three-lane passing zones interspersed every three to four miles. The inter-passing-zone stretches of the two-lane highway consisted of three to four miles of a variety of terrain, including both horizontal and vertical curves (hilly terrain) and straight and level sections. The speed limit for inter-passing-zone stretches of highway was marked as 65 mph and advisory signs for curves were included. Passing zones consisted of a two-mile length of straight and level (0% grade) roadway with standard advisory and regulatory signs preceding each zone in their typical locations (see Figure 1). For each passing zone, the full two lanes separated by white dashed lane markings was one mile long, with a 1/8 mile lane-addition transition, and a 1/8 mile lane-reduction transition. Each passing zone simulated one of ten different set of signage or roadway markings, hereafter referred to as *scenarios* (see Figures 2-11):

Table 1. The ten passing zone scenarios

0. Baseline	**5.** Transverse lines
1. Advisory	**6.** Lane narrowing
2. Regulatory	**7.** Parallax
3. Regulatory plus advisory	**8.** Force right/Neutral zone
4. Chevrons	**9.** Transverse lines with middle segment

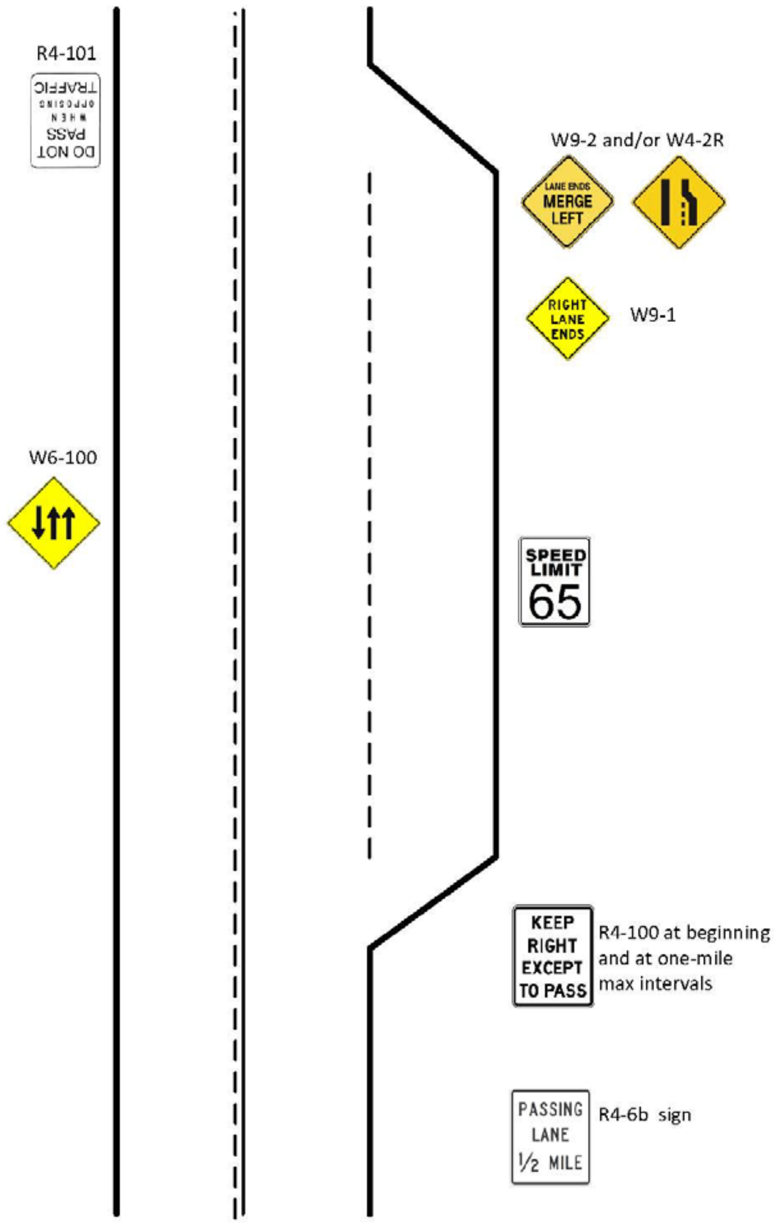


Figure 2. Schematic view of Scenario 0 – Baseline (geometry not to scale).

This scenario was developed to simulate the conditions presently implemented in passing zones on Alaska rural highways.

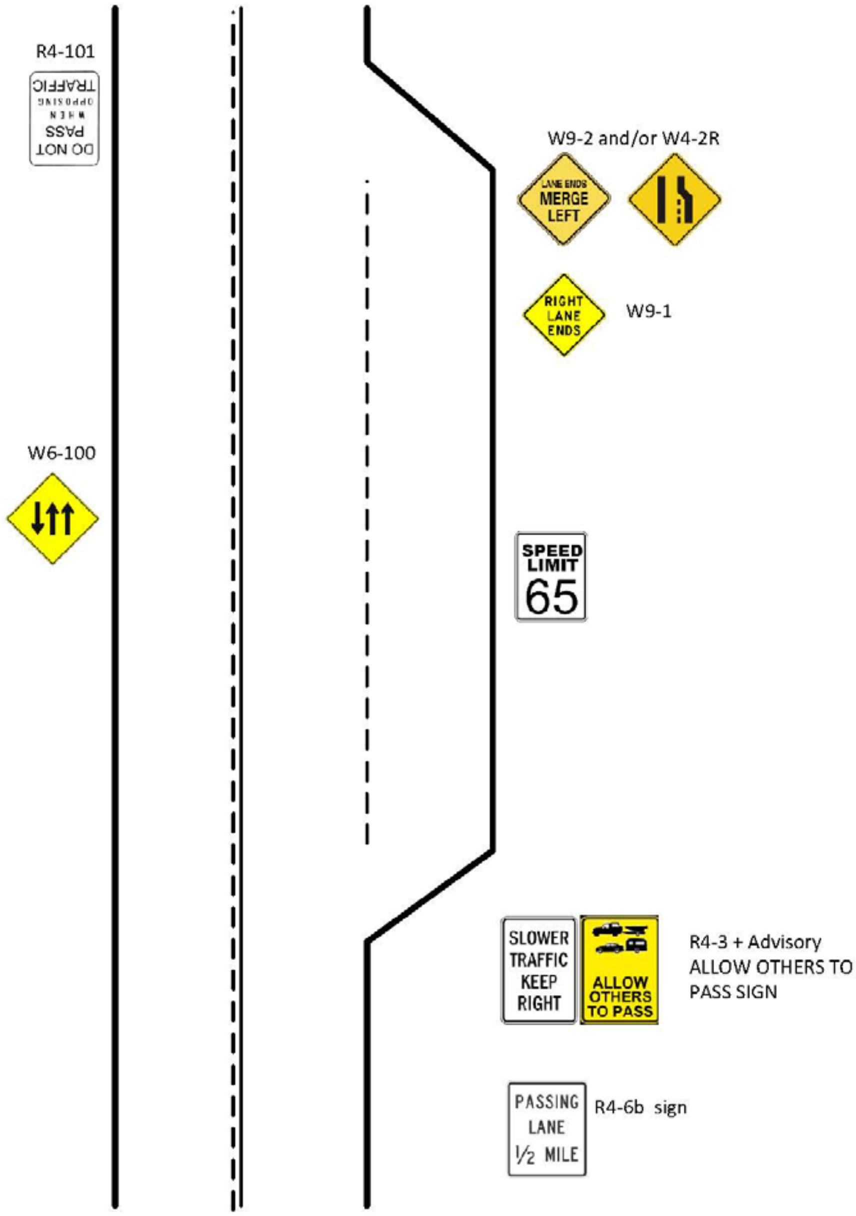


Figure 3. Schematic view of Scenario 1 – Advisory (geometry not to scale).

This scenario was identical to Scenario 0 – Baseline with the addition of the advisory sign “Allow other to pass” next to the “Slower traffic keep right” sign, which replaced the “Keep right except to pass” sign.

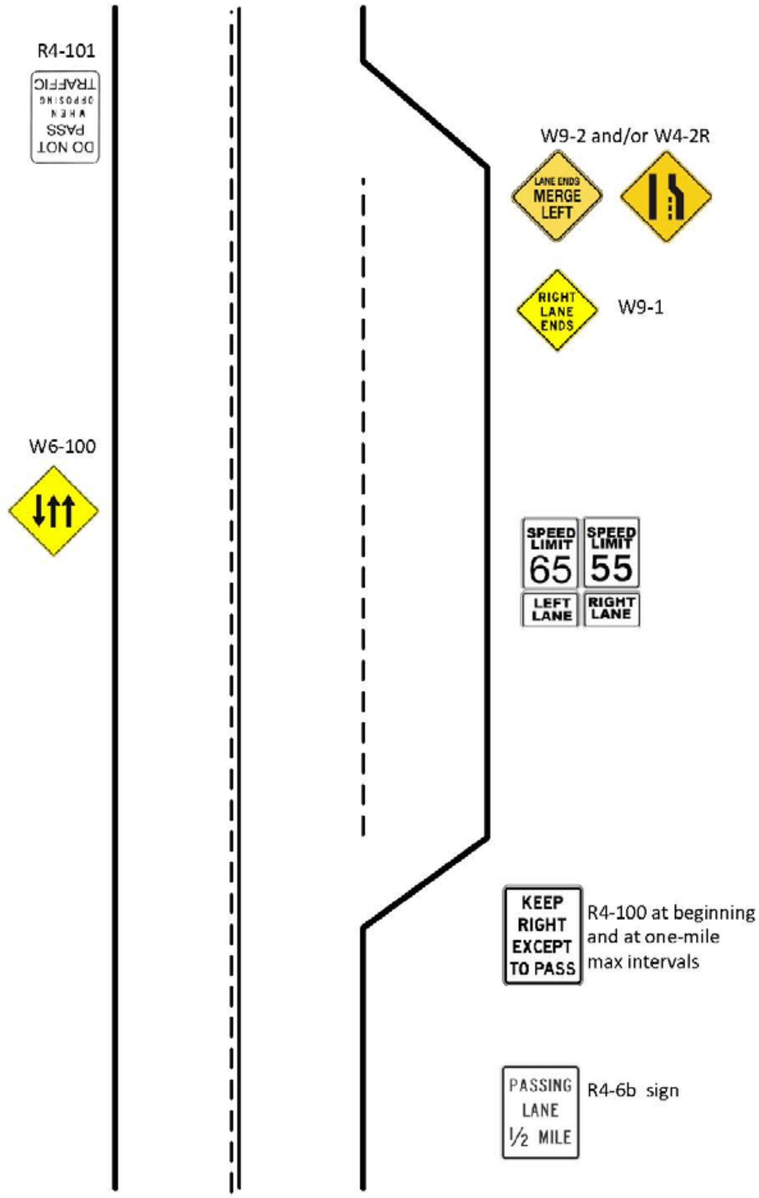


Figure 4. Schematic view of the Scenario 2 – Regulatory with right lane reduced speed limit (geometry not to scale).

This scenario was identical to the Baseline Scenario except for the addition of a split speed limit for the left and right lanes. Right lane speed limit was reduced to 55 mph.

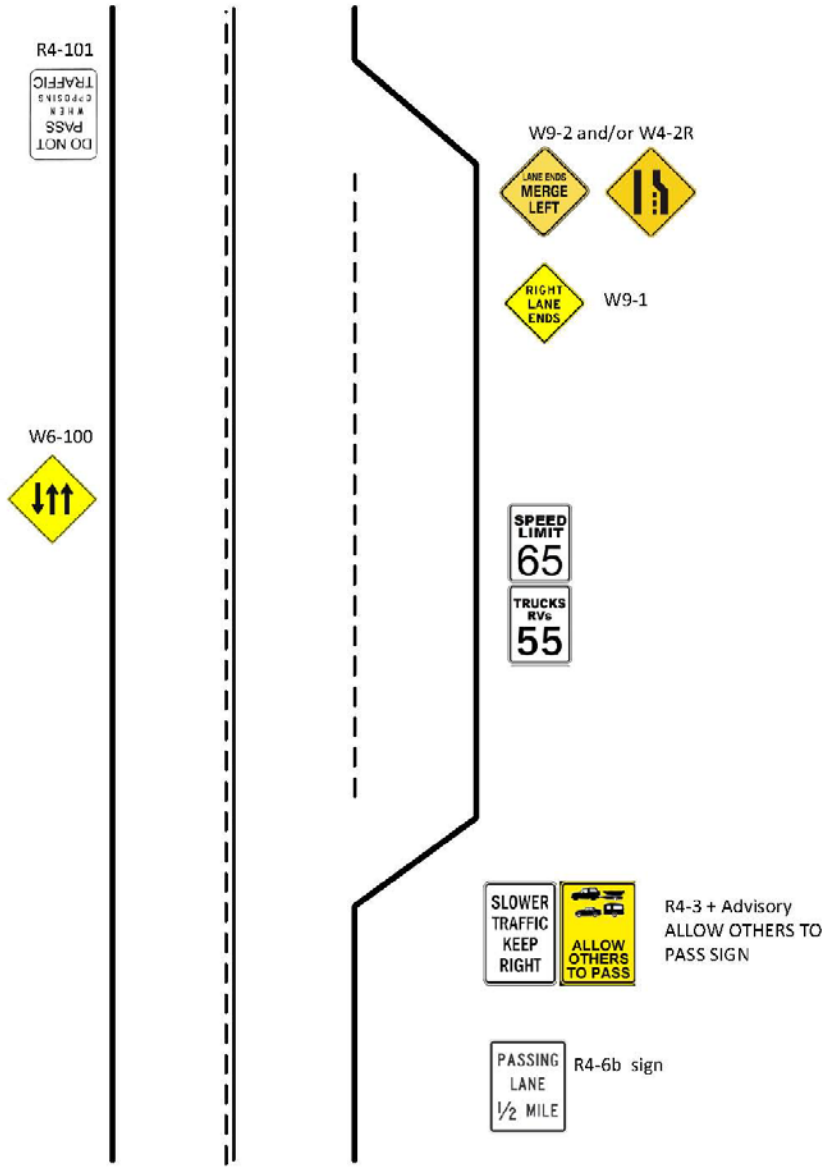


Figure 5. Schematic view of Scenario 3 - Regulatory with truck/RV speed limit plus advisory (geometry not to scale).

This scenario was identical to the baseline scenario except for the addition of the advisory and "Slower traffic keep right" signs included in Scenario 1 and a reduced speed limit (55 mph) for Trucks and RVs.

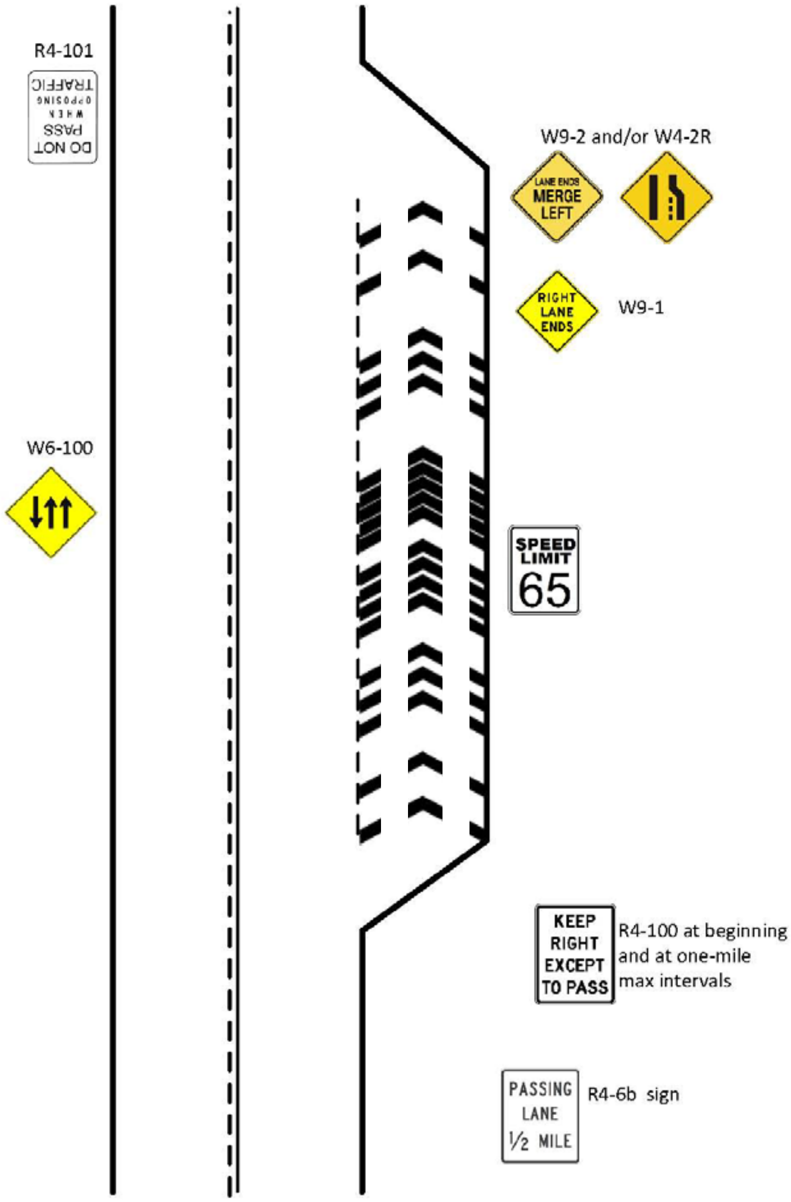


Figure 6. Schematic view of Scenario 4 – Passive speed reduction using chevrons (geometry not to scale).

This scenario was identical to the Baseline Scenario except for the addition of partial chevrons painted on the road surface with longitudinal spacing logarithmically-decreasing over the first ¼ mile, then constant for ½ mile, and finally logarithmically-increasing over the last ¼ mile of the passing zone (see text for details).

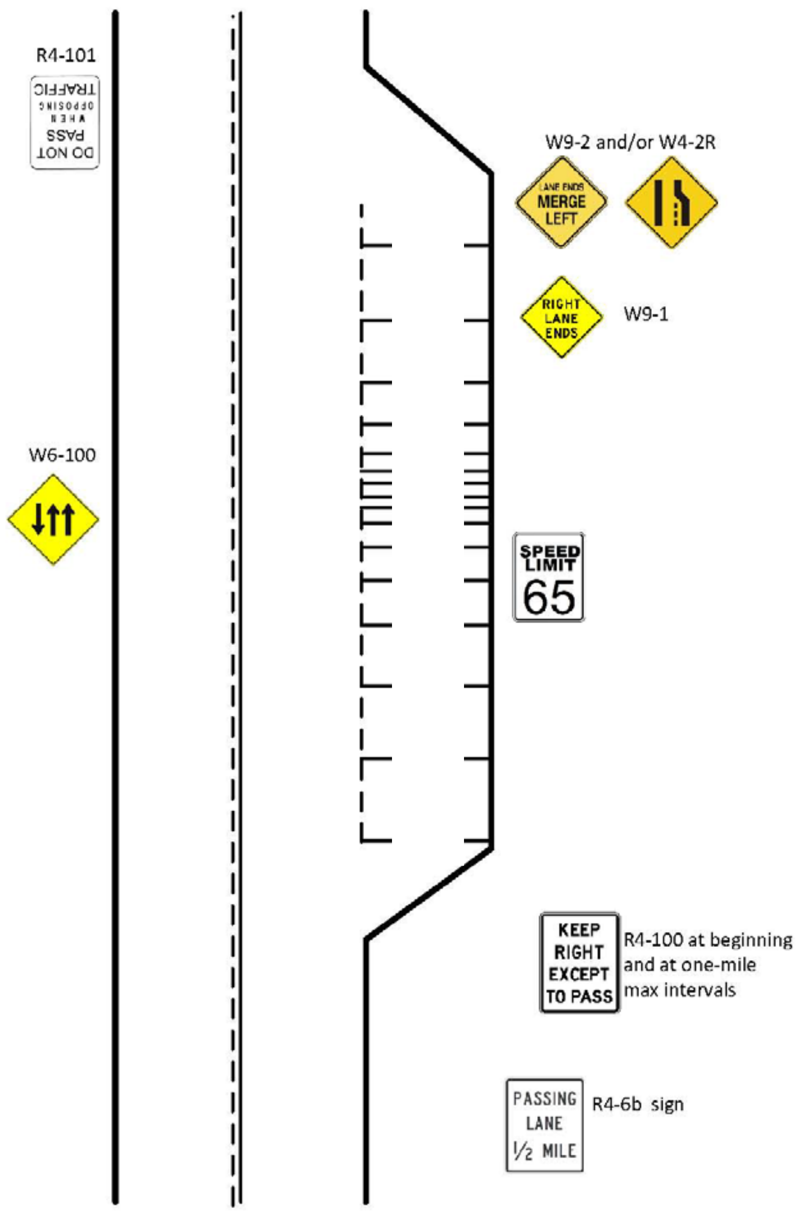


Figure 7. . Schematic view of the Scenario 5 – Passive speed reduction using transverse lines (geometry not to scale).

This scenario was identical to the Baseline Scenario except for the addition of transverse lines painted on the road surface with longitudinal spacing logarithmically-decreasing over the first ¼ mile, then constant for ½ mile, and finally logarithmically-increasing over the last ¼ mile. Longitudinal spacing parameters were identical to Scenario 4 – Chevrons (see text for details).

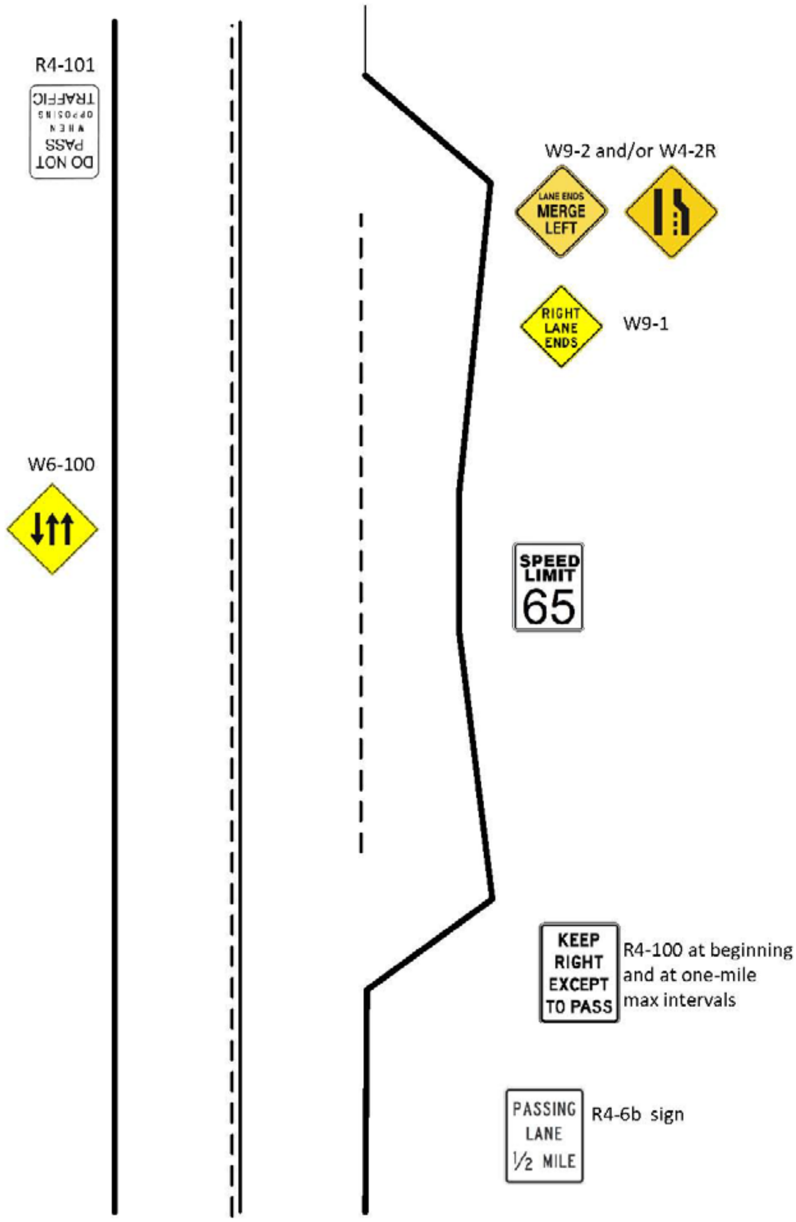


Figure 8. Schematic view of Scenario 6 – Passive speed reduction with lane narrowing (geometry not to scale).

This scenario was identical to the Baseline Scenario except for a linear narrowing of the right lane edge lines from 12' to 10' over the first ¼ mile, followed by a constant 10' width for ½ mile, then a gradual linear expansion to the original 12'lane width over the last ¼ mile.

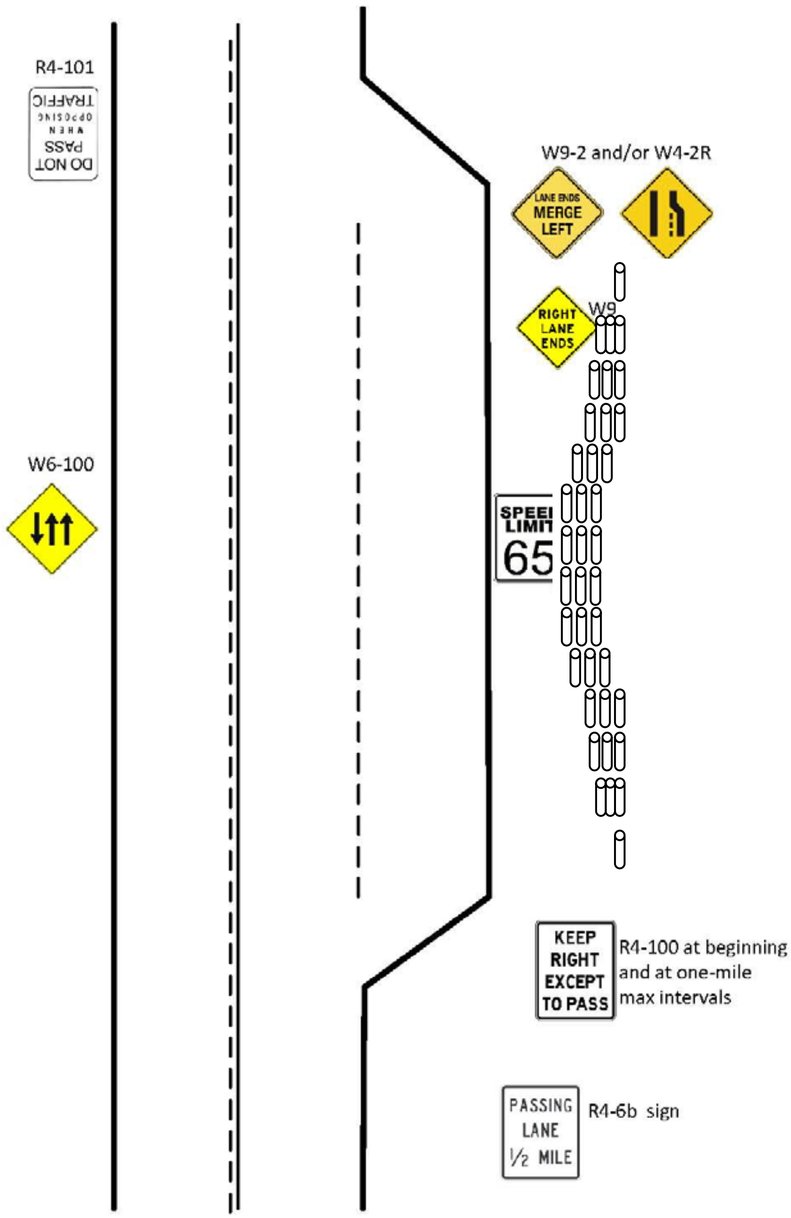


Figure 9. Schematic view of Scenario 7 – Passive speed reduction with poles creating optical parallax along the side of the road (geometry not to scale).

This scenario was identical to the Baseline Scenario except for the addition of 10' yellow poles placed along the side of the road with longitudinal spacing parameters were identical to Scenario 4 – Chevrons. Lateral spacing and the number of poles also varied (see text for details).

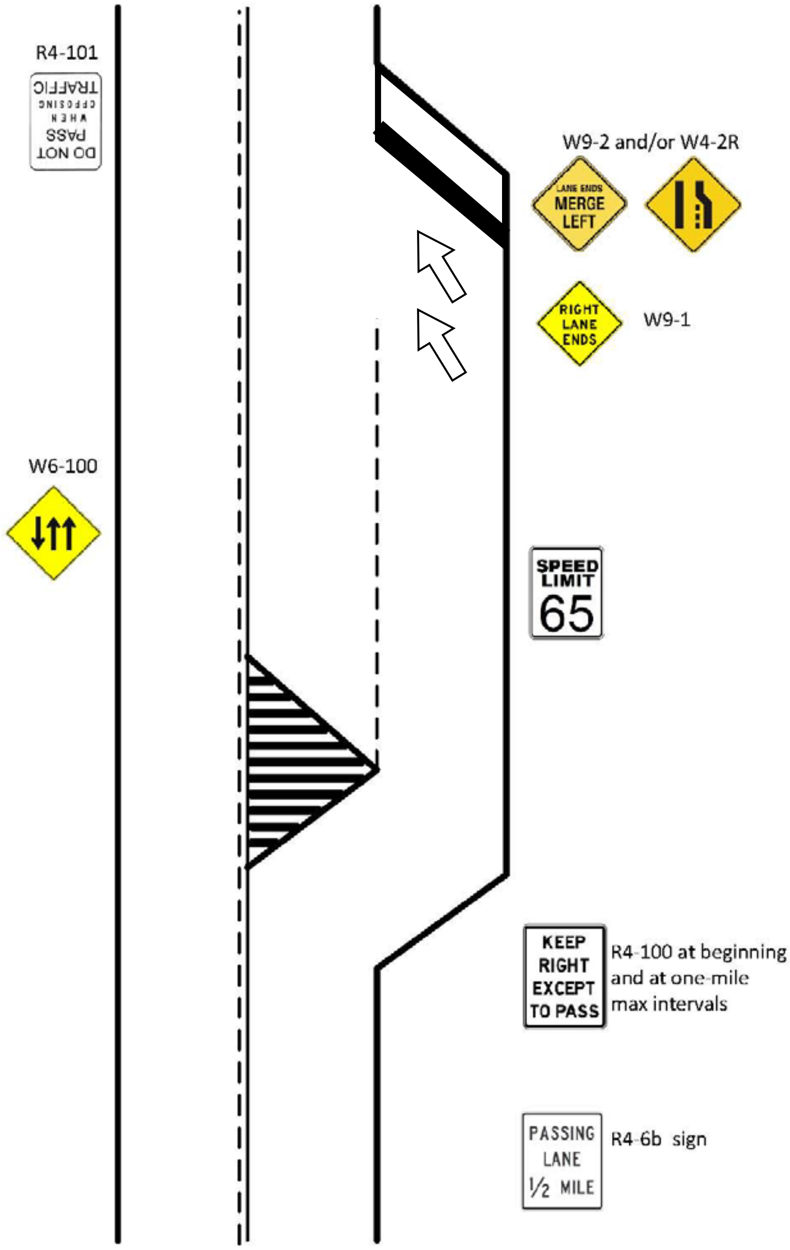


Figure 10. Schematic view of Scenario 8 - Force right at lane addition and neutral zone with arrows at lane reduction (geometry not to scale).

This scenario was identical to the Baseline Scenario except for the addition of a "force right" center line at the beginning of the passing zone and an early return with arrows, rumble strip, and a neutral zone at the end of the passing zone (see text for details).

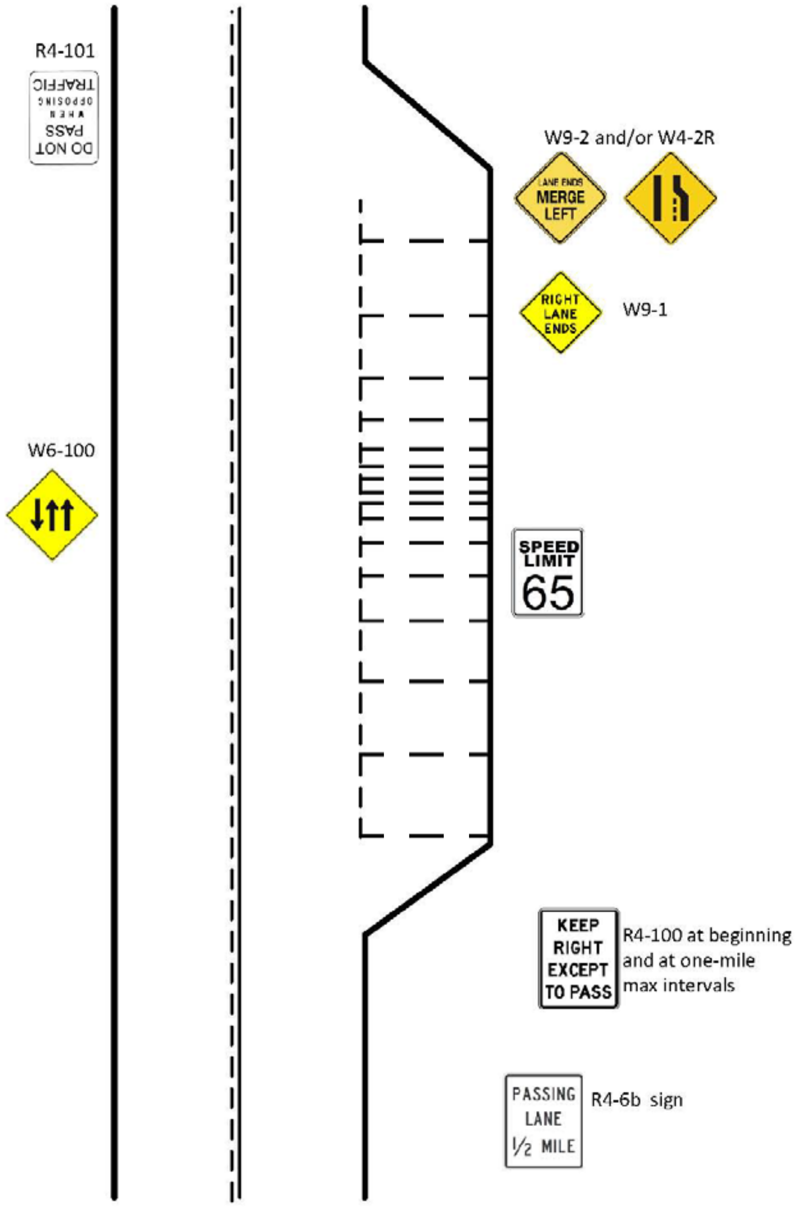


Figure 11. Schematic view of Scenario 9 - Passive speed reduction using transverse lines with a middle segment (geometry not to scale).

This scenario was identical to the Scenario 5 – Transverse Lines except for the addition of a middle segment painted on the road surface (see text for details).

Scenario Descriptions

Scenario 0: *Baseline.* This scenario simulated the conditions presently implemented in passing zones on Alaska rural highways. All other passing zone scenarios were variations on this baseline scenario and shared all elements except for the differences described below.

Scenario 1: *Advisory.* This scenario replaced the "Keep Right Except to Pass" sign with a "Slower Traffic Keep Right" sign and added the advisory sign "Allow Others to Pass" next to the "Slower Traffic Keep Right" sign.

Scenario 2: *Regulatory with right lane reduced speed limit.* This scenario changed the 65 mph of the Baseline Scenario 0 to a split speed limit for the left and right lanes, with the right lane speed limit reduced to 55 mph.

Scenario 3: *Regulatory with truck/RV speed limit plus advisory.* This scenario added the same advisory and "Slower Traffic Keep Right" signs included in Scenario 1 and combined it with a reduced speed limit of 55 mph for Trucks and RVs.

Scenario 4: *Passive speed reduction using chevrons.* This scenario added partial chevrons painted on the road surface to the Baseline Scenario 0. The partial chevrons consisted of groups of ten 5.9" wide white lines extending from the lane edge markings into the lane at an angle of 30 degrees toward the direction of travel and spaced 2" apart. Each group thus extended 6' 7" longitudinally along the roadway. The lines extended 1.5' laterally toward the center of the lane from each edge line, then left a 3' lateral gap before starting again for the center 3'-wide "^" shape. This left two 3'-wide paint-free gaps for vehicles tires to contact the road. The chevron groups started at the point where the two full passing lanes divided by a dashed white line began, with the first five groups spaced longitudinally at a distance of 42’ measured from the beginning of one group of chevrons to the beginning of the next group. After the fifth group of Chevrons, the spacing decreased by a factor of 0.988 for the next 33 groups, reaching a minimum of 26.8’ between the 38th and 39th group, which was located ¼ mile into the passing zone. For the next ½ mile, 61 groups of chevrons occurred at a constant longitudinal spacing of 26.8’. For the last ¼ mile of the full two lane section of the passing zone, the spacing increased by a factor of 1/0.988 = 1.012 for the first 34 chevron groups and then remained at a constant 42’ for the final 5 chevron groups.

Scenario 5: *Passive speed reduction using transverse lines.* This scenario added transverse lines painted on the road surface to the Baseline Scenario 0. The transverse lines consisted of 2’-wide lines extending orthogonally from the lane edge markings into the lane 1.5’. Longitudinal spacing of the transverse lines was identical to the chevrons described in Scenario 4.

Scenario 6: *Passive speed reduction with lane narrowing.* This scenario was identical to the Baseline Scenario 0 except for a linear narrowing of the right lane edge line such that the lane width reduced from 12’ to 10’ over the first ¼ mile, remained a constant 10’ width for the next ½ mile, then linearly expanded to the original 12’ lane width over the last ¼ mile.

Scenario 7: *Passive speed reduction with poles creating optical parallax along the side of the road.* This scenario added groups of yellow poles extending 10’ above the ground along the side of the road to the Baseline Scenario 0. The poles were 6” in diameter and painted with the same yellow color as the center dividing line of the highway. The longitudinal spacing of the pole groups decreased logarithmically during the first ¼ mile, was constant for ½ mile, and increased logarithmically over the last ¼ mile in a manner identical to Scenario 4: Chevrons. The number and lateral spacing of the poles within each pole group also changed over these segments of the passing zone.

The initial four pole groups and last four pole groups—corresponding to the initial and final four constant longitudinal gaps—contained only one pole, located 60' laterally from the right-hand edge line of the roadway. All other pole groups contained 3 poles, whose inter-pole lateral spacing increased linearly from 1' for the 5th pole group to 10' for the 16th pole group. For pole groups 1-16, the farthest pole was always located 60' from the roadway right-hand edge line, therefore for the 16th pole group the near and middle poles were located 40' and 50' from the edge line, respectively.

Pole groups 17-38 continued with 10' lateral spacing but the distance of the poles from the roadway right-hand edge line decreased linearly from 40, 50, and 60' to 15, 25, and 35' (respectively) at ¼ mile into the full 2-lane segment of the passing zone. For the next ½ mile of the passing zone 61 pole groups had constant lateral and longitudinal spacing. Over the last ¼ mile of the full 2-lane passing zone pole groups 62-83 had 10' lateral spacing but linearly increased in distance from the right edge-line of the roadway until the distance again reached 40, 50, and 60' for the nearest, middle, and furthest pole, respectively. For the next 12 pole groups, 84-96, inter-pole lateral spacing linearly decreased from 10' to 1' with the furthest pole located 60' laterally from the right roadway edge line, followed by the last 4 single pole groups.

Scenario 8: *Force right at lane addition and neutral zone with arrows at lane reduction.* This scenario added two elements to the Baseline Scenario 0: 1) a "force right" center line at the beginning of the passing zone; and 2) an early return with arrows, rumble strip, and a neutral zone at the end of the passing zone. A rumble strip was simulated under this line to create a loud rumble sound when driven upon, which shortened the passing zone by 200 feet leaving Standard arrows from the MUTCD pointing diagonally toward the left-lane preceded the early return neutral zone .

Scenario 9: *Passive speed reduction using transverse lines with a middle segment.* This scenario added a middle segment to the transverse lines painted on the road surface for the Transverse Lines Scenario 5. The middle line segment was 2' wide and 3' long placed exactly in the lane center, providing 3' wide unpainted pavement between the center and outer transverse line segments.

Table 2. The 10 unique orders of scenarios assigned to participants

Participant	Order of Presentation for Passing Lane Scenarios									
1, 11, 21	0	1	9	2	8	3	7	4	6	5
2, 12, 22	1	2	0	3	9	4	8	5	7	6
3, 13, 23	2	3	1	4	0	5	9	6	8	7
4, 14, 24	3	4	2	5	1	6	0	7	9	8
5, 15, 25	4	5	3	6	2	7	1	8	0	9
6, 16, 26	5	6	4	7	3	8	2	9	1	0
7, 17, 27	6	7	5	8	4	9	3	0	2	1
8, 18, 28	7	8	6	9	5	0	4	1	3	2
9, 19, 29	8	9	7	0	6	1	5	2	4	3
10, 20, 30	9	0	8	1	7	2	6	3	5	4

Key to scenario numbers:

0. Baseline condition
1. Advisory
2. Regulatory
3. Regulatory + Advisory
4. Chevrons
5. Transverse Lines
6. Lane Narrowing
7. Parallax
8. Force Right/Neutral Zone
9. Transverse Lines with middle segment

We developed 10 unique counter-balanced orders for the 10 passing scenarios such that each scenario occurred equally often in each place of the order and preceded and followed every other scenario an equal number of times. These orders are listed in Table 2. Each passing zone also included a pseudo-random headwind-tailwind disturbance profile to induce participants to make accelerator pedal movements to maintain constant speed. The wind disturbances profiles were defined by 5 velocities: strong head-wind (defined as -100 mph in the MiniSim software), head-wind (-50 mph), zero, tail-wind (50 mph), and strong tail-wind (100 mph), each presented twice in a pseudo-random order for 1/10 mile segments of the passing zone. While the magnitude of these disturbances as defined in the Minisim software seem extreme, their effect in accelerating the vehicle was actually very modest: In the absence of accelerator or brake inputs, these disturbances changed the vehicle speed by a maximum of 3-4 mph. Further, because the wind disturbances always summed to zero within a passing zone, the cumulative effect of each disturbance on the mean vehicle speed in a passing zone was negligible. The order of the wind disturbances were balanced across the 10 passing zones such that each wind velocity profile was paired with each passing lane scenario an equal number of times.

The simulation also included traffic, with cars and trucks in front of and behind the participant's vehicle and in the oncoming lane. Traffic density in the oncoming lane was moderate, with oncoming vehicles passing every 10-20 seconds. Traffic density in the driver's lane was manipulated differently for the two experiments (see below), but for both experiments each passing zone was "reset" during the inter-zone highway stretch by scripting the vehicles from the previous passing zone to pull off onto the shoulder, while simultaneously scripting a new set of 9 vehicles to be created out of sight around corners ahead of and behind the driver. This procedure ensured that each passing zone had nearly identical traffic conditions, with the same number of cars in front and behind the driver.

Apparatus

We used identical apparatus for both Experiments 1 and 2. A seven video channel National Advanced Driving Simulator (NADS) MiniSim rendered the simulations and collected our behavioral data. Participants “drove” the simulations from an instrumented cab based on a 2001 Chevrolet S10 pick-up truck (see Figure 12). The cab was located such that the driver’s eyes coincided with the projected eye-point of the simulated environment. Three Canon REALiS SX800 projectors front-projected the main forward view of the environment on three white screens arranged as three sides of an octagon whose center was coincident with the projected eye-point of the simulation, 1.8 m from the center of each of the three screens.

These screens comprised a 135 x 33.75 degree (horizontal x vertical) field of view with spatial resolution of 4200 x 1050 pixels (H x V) and a refresh rate of 60 Hz. In addition to the main view, 0.203 m (8”) Liquid crystal display (LCD) screens, each with a spatial resolution of 800 x 600 pixels (H x V), were mounted to the left and right side rearview mirror housings of the S10 cab. The center—windshield-mounted—rearview mirror of the cab reflected the view out

Figure 12. Overhead view of Chevy S-10 cab with the 3 Main forward displays and right-side mirror display visible. The instrument cluster, left side mirror, and center rear view mirror are not visible.

the rear window of the cab, which was filled by imagery displayed on a 1.65 m (65”) plasma screen with 1280x720 pixel resolution and 60 Hz refresh rate located directly behind, and completely filling, the window opening. The seventh MiniSim video channel displayed the dashboard instrument cluster (tachometer, speedometer, engine temperature gauge, gear selection, fuel gauge) on a 0.254 m (10”) LCD with a spatial resolution of 1280 x 800. This display was mounted in place of the normal mechanical analog instrument cluster of the S10. All seven displays were rendered by the NADS MiniSim software running under the Windows 7 operating system on a single graphics workstation containing a six-core Intel Core I7 processor running at 3.9 GHz, 32 GB of RAM, and two NVidia video display adapters. A GeForce GTX680 routed through a Matrox T2G-D3D-IF controlled the three main displays. This video adapter also rendered the dashboard and right side-mirror displays. A GeForce GTX660TI video adapter rendered the left side-mirror and center rearview mirror displays. A 5.1 channel audio system used the 4 speakers mounted in the cab doors and B pillars and a sub-woofer mounted behind the driver’s seat to produce automobile and road sounds.

A Suzo-Happ model 95-0800-10k USB Game Controller Interface (UGCI) connected the steering wheel, gear selector, turn signals, and brake and accelerator pedals to the MiniSim. The original S10 steering wheel provided 540 degrees of steering range and was self-centering. The original S10 brake and throttle controls provided haptic displacement feedback similar to a normal automobile. A center console housed an automatic gear selector from a 2001 Honda Civic to provide participants with a standard interface for gear selection.

Procedure

Participants were treated in accordance with a university-approved protocol governing the use of human subjects in research. Prior to starting the experiments, all participants were read a general description of the study, warned of the risks involved (primarily motion sickness), and asked to sign a consent form. Next, the instructions were read to participants. Importantly, these instructions emphasized that participants should imagine themselves driving on a rural Alaskan highway and that they should act normally in obeying traffic laws and driving etiquette.

To ensure all participants had a firm understanding of the signs that were displayed in this experiment, each received a multiple choice sign quiz (see Appendix A) administered through a PowerPoint slide presentation. The quiz included questions on familiar signs (speed limit, passing lane half mile, right lane ends), as well as new signs developed for the passing scenarios. If any questions were missed, the correct response was explained to participants to ensure understanding before proceeding to the next sign.

Following the sign quiz, participants were given a five minute test drive on a rural two-lane stretch of road with horizontal and vertical curves to familiarize themselves with the simulator and the sensitivity of the controls. Once participants were comfortable with the controls, the experiment was started. At approximately mile 25 of the drive—halfway through—a message appeared on the main screens informing the participant to pull off on the shoulder for a break. During this break, we asked participants to exit the simulator and walk around for a few minutes to rest and stretch their legs. Participants then completed the last 25 miles of the circuit, after which they were asked a number of debriefing questions aimed to assess the immersive quality of the simulation, their degree of fatigue and or motion sickness experienced during the experiment, whether participants noticed our experimental manipulations, and what hypotheses they may have formed as to the nature of the experiment. Following these questions, we informed participants of the nature and purpose of the study.

CHAPTER 3: EXPERIMENT 1 RV-TOWING DRIVERS

We designed Experiment 1 to test the efficacy of our different passing zone scenarios on the speed and lane choice of RV-towing drivers. Though we hoped these drivers would choose to use the right hand lane, we also expected that the different passing zone scenarios might affect lane choice, so we chose to not explicitly instruct our participants to use the right lanes of the passing zones. Such instructions could have potentially altered our participants' normal driving behavior. To induce a right lane choice we therefore relied upon subtle instructions for participants to imagine themselves pulling a RV trailer, explicit inclusion of a simulated trailer behind the vehicle filling much of the center rearview mirror, and following traffic pressure.

Method

Participants. Thirty-three participants with valid driver's licenses were tested for this experiment. Three participants failed to complete the experiment due to motion sickness; their data were excluded from our analysis. Participants included twenty students from the University of Idaho, who received class extra credit for their participation. We recruited the remaining 10 participants using an online advertisement, and compensated them $30 for their participation. All participants wore corrective lenses if they were required to wear them while driving. Participants had an average age of 29.7, ranging from age 18 to 62, with an average of 14.4 years of driving experience. Additionally, 57% of participants had previous experience pulling a trailer.

Stimuli. Traffic in the participants' direction of travel was specifically designed to induce a feeling of following traffic pressure. In each inter-passing zone stretch of highway a new set of 9 vehicles was created out of sight both ahead and behind the participant's vehicle. Two leading vehicles were scripted to maintain a speed of 45 mph until the participant's vehicle caught up to them, at which time they increased speed to maintain 600 and 1000 feet gaps in front of the participant's vehicle. These gaps were close enough to induce a feeling of driving in traffic, but also far enough ahead that our RV-towing drivers would not feel pressured to try to pass. The seven following vehicles were scripted to induce pressure on our RV-towing drivers to allow them to pass. These vehicles were scripted to drive at moderately high speeds to catch up to the participant's vehicle, at which time they maintained gaps of 100 feet between vehicles. Hence the seventh vehicle followed the participant's vehicle at a distance of 700 feet. Once the participant reached a passing zone and pulled into the right-hand lane, this gap maintenance terminated and the vehicles accelerated to 74 mph to pass. The RV-towing drivers were thus induced to stay in the right lane throughout the length of the passing zone. To discourage participants from driving too fast, a simulated police siren sounded whenever their speed exceeded 75 mph.

Procedure. We instructed each participant to imagine they were driving home from a recreational out of town weekend in Alaska where they had been boating or camping, and that they were pulling a trailer behind them. They were explicitly instructed to follow all rules and etiquette they would normally use while driving a vehicle pulling a trailer. (The full instructions may be seen in Appendix B). The entire experimental session lasted 90 minutes.

Results

To increase passing efficiency, our passing lane scenarios needed to affect two driver behaviors: lane-control and speed-control. Efficient passing lane designs encourage slower drivers to move quickly to the right hand lane and slow down so that more vehicles may pass within the length of the passing zone. Safe passing zones also require a smooth merging of traffic before the passing lane has been eliminated. Here we will examine these behaviors and how they differ across the 10 passing zone scenarios.

Lane Control. We did not explicitly instruct participants to use the right lane and allow others to pass, but rather implicitly encouraged participants to use the right-hand lane through the simulation of pulling a RV trailer, combined with pressure from overtaking traffic and instructions to "observe normal driving etiquette." Because a primary aim of Experiment 1 was to compare how the scenarios differentially-affected right-lane drivers, we hoped these experimental operations would implicitly induce our drivers to choose to use the right-hand lane. It appears these operations worked: as can be seen in Figure 13, participants moved to the right lane within the first ¼ mile (1320 ft.) over 99% of the time, and averaging across all the scenarios, participants occupied the right-hand lane of the one-mile long two-lane segment of the passing zone 90.55% of the time.

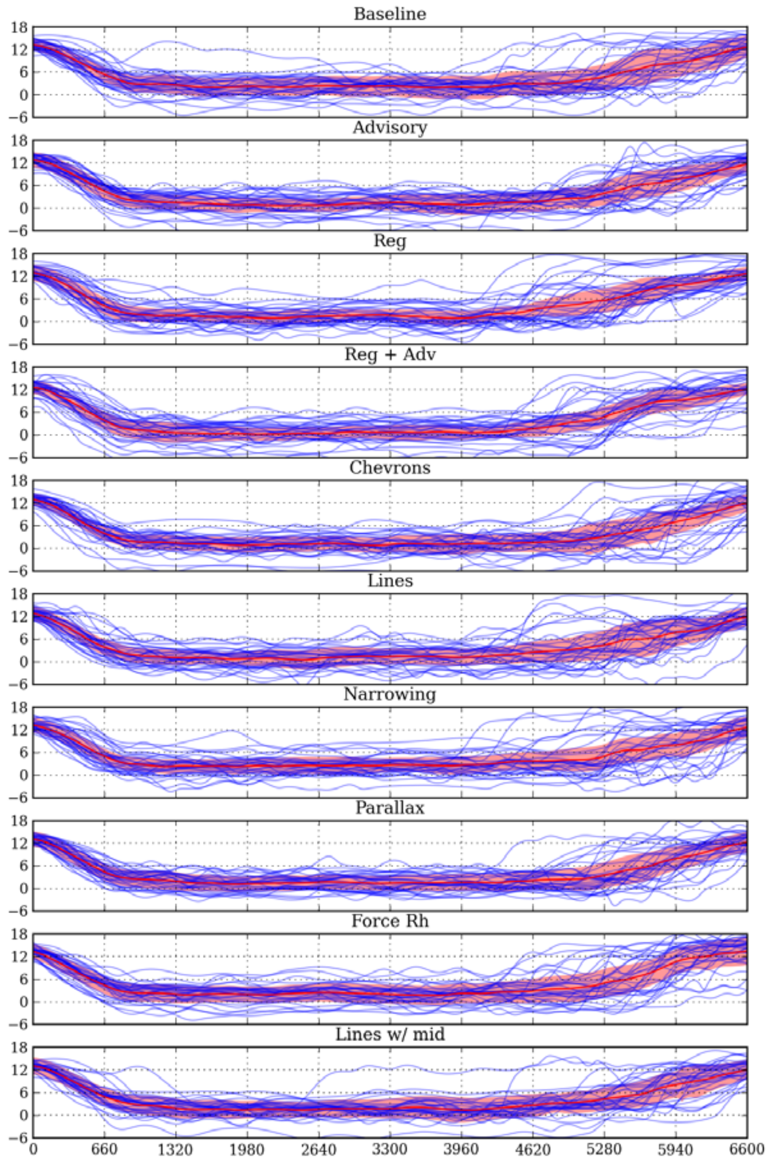


Figure 13. Distance Traveled from Beginning of Passing Zone (ft.)

Vehicle lane deviation in feet from the center of the right lane as functions of distance for each scenario. The center of the left lane corresponds to 12 feet on the y-axis. The distance axis extends from the beginning of 1-to-2 lane-addition transition through the end of the 2-to-1 lane-reduction transition. The 1-mile full-two-lane segment extends from 660 to 5940 ft. For each panel, the blue traces represent data from individual participants. The bright red trace represents the ensemble average. The red fills represents 95% confidence intervals on the ensemble averages.

Lane choice and control for the full two-lane segment. We assessed the effects of the 10 passing lane scenarios on lane control by examining the percentage of time spent in each lane and lane deviations within a lane during the one-mile full-two-lane segment of the passing zone—for the moment ignoring the 1/8 mile long diverging and merging transition zones. For each participant, and for each of the passing zones scenarios, we computed the arithmetic mean and standard deviation for each of these measures. We used Welch's test to determine whether the means and standard deviations across the ten scenario conditions were statistically equivalent[1]. If Welch's test indicated statistically reliable differences among the 10 means or standard deviations, we determined which pairs of means or standard deviations differed reliably from one another using the Games-Howell procedure, which forms a pooled variance estimate for each individual pairwise comparison. We used a Type I error probability of $\alpha = .05$ as the decision criterion for statistical reliability (the probability of any differences being due to chance was less than .05).

These analyses found a borderline effect of scenario on the proportion of time spent in the right hand lane [$W'(9, 117.902) = 2.104$, $p < 0.05$] with the only reliable pairwise differences occurring between the chevron scenario 4 (m = 94.3%) and the regulatory scenario 2 (m = 87.2%) and the regulatory + advisory scenario 3 (m = 87.9%). All other pairwise comparisons were non-significant. Examination of Figure 13 suggests that the greater time spent in the right lane for the chevron scenario may have been carried primarily by the

[1] The Welch procedure is a non-pooled test statistic in that it does not pool variability from heterogeneous sources, therefore type I errors are not subject to inflation from potential violations of homogeneity of variance.

latter stages of the passing zone—the merge left appears to be somewhat delayed compared to scenarios 2 and 3.

We found no statistically reliable differences between the scenarios for the mean position within a lane [$W'(9, 117.897) = 1.211$, $p > 0.05$], the standard deviation of position within a lane [$W'(9, 118.065) = 1.574$, $p > 0.05$], the mean steering angle . [$W'(9, 118.001) = 1.284$, $p > 0.05$], or the standard deviation of steering angle [$W'(9, 117.794) = 1.071$, $p > 0.05$]. These results suggest that precise control of steering through the one-mile two-lane segment of the passing zone was not reliably affected by the different scenarios. The lack of effects can be easily seen in Figure 13 between distances of 660 and 5940 ft.: participants overwhelmingly chose to drive in the right-hand lane, and maintained lane position throughout the one mile long section of full multiple lanes with statistically equivalent precision regardless of the passing lane scenario.

Lane maintenance and steering control for all passing zone segments. To assess differences in lane maintenance and steering control across the entire passing zone, including both the 1/8th-mile lane-addition and 1/8th-mile lane-reduction transitions, we used 3 x 10 factorial repeated-measures analyses of variance (ANOVAs). These analyses compared the means and standard deviations of steering wheel angle and lane deviation for each factorial combination of the 3 passing zone segments (first 1/8 mile lane-addition transition section, next one-mile long full two-lane section, and last 1/8 mile lane-reduction transition) and the 10 scenarios enumerated in Table 1. All main effects and interactions were interpreted using Greenhouse and Geisser's correction for violations of sphericity.

The analysis of mean steering angle identified a main effect of passing zone segment [$F(2, 54.83) = 5.143$, $p < .05$, η^2_G = 0.013, ε_{GG} = 0.945, observed-power = 1.00]. Greater mean steering angle angles were found for both the lane addition (μ = .094) and lane reduction (μ = .108) segments as compared to the full 2-lane segment 2 (μ = .015). Passing zone scenario had no effects on mean steering angle (p > .05). However, the analysis of the standard deviation (SD) of steering wheel angle identified main effects of segment [$F(2, 57.80) = 4.587$, $p < .05$, , η^2_G = 0.009, ε_{GG} = 0.997, observed-power = 1.00], scenario [$F(9, 142.4) = 4.356$, $p < .05$, η^2_G = 0.039, ε_{GG} = 0.546, observed-power = .51], and an interaction between segment and scenario [$F(18, 185.2) = 3.24$, $p < .05$, η^2_G = 0.046, ε_{GG} = 0.355, observed-power = .099].

As can be seen in Figure 14, the segment-scenario interaction was produced primarily by differences in variability in steering during the lane-reduction segment 3 across the scenarios; steering standard deviation was statistically equivalent for all scenarios for the lane addition and full 2-lane segments. During the lane-reduction segment, scenarios 6 (Lane Narrowing) and 8 (Force Right) exhibited significantly higher standard deviations in steering angle than the baseline scenario 0. Drivers had to steer more actively for these scenarios. The extremely high standard deviation in steering angle for the force right/neutral zone lane-reduction may reflect the shortened passing zone forcing drivers into more steering inputs. In contrast, scenarios 2 (Advisory), 3 (Regulatory), and 4 (Regulatory + Advisory) all exhibited significantly lower standard deviations in steering angle than the baseline scenario 0, consistent with less steering activity for these scenarios during the lane-reduction segment. Lower activity may reflect the

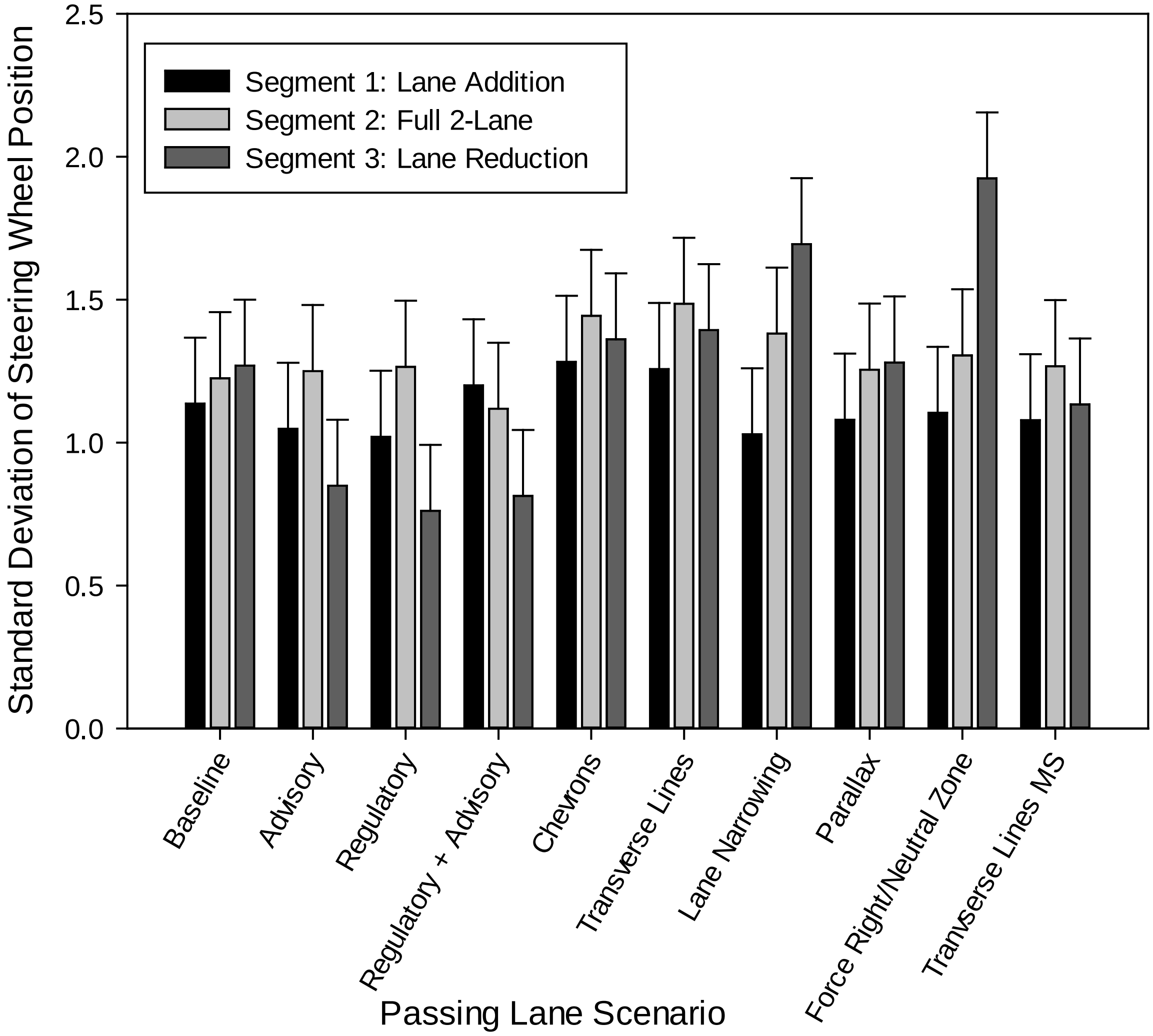


Figure 14. Standard deviations of steering wheel angle for each segment and scenario combination. Whiskers represent a within-subjects 95% confidence interval.

fact that drivers also slowed down more for these scenarios and had a greater margin of safety for the lane-reduction (see speed analysis below).

The segment of the passing zone reliably affected mean lane deviation [$F(2, 44.469) = 60.527$, $p < .05$] with a greater mean deviation for the first 1/8 mile lane addition segment (μ =

1.590 ft.) and last 1/8 mile lane reduction segment (μ = 0.934 ft.) as compared to the middle one-mile, full-two-lane segment (μ = 0.479 ft.). The segment effect on mean lane deviation reflects the increasing deviations occurring as participants changed lanes in the transition segments of the passing zones. The segment of the passing zone also reliably affected the standard deviation of lane deviation [$F(2, 84.046) = 127.273$, $p < .05$] with a greater standard deviation in lane deviation for the first 1/8 mile lane addition segment (σ = 1.914 ft.), than the middle one-mile, full-two-lane segment (σ = 1.598 ft.), and last 1/8 mile lane reduction segment (σ = 1.106 ft.). Note that across the three passing zone segments the pattern of the standard deviations are not ordered the same as the pattern of means. The first lane-addition segment has the highest mean and standard deviation of lane deviation—probably reflecting the consistent changing of lanes to the right lane.

The middle segment, however, has the lowest mean lane deviation and the intermediate standard deviation, while the last lane-reduction segment has the intermediate mean and the lowest standard deviation. The standard deviation of lane deviation reflects the precision (variable error) of lane maintenance while the mean lane deviation reflects the accuracy (or constant error) of lane maintenance. Hence, drivers are least accurate and precise in controlling lane position during the initial lane-addition transition, most accurate in controlling lane position during the middle segment, and most precise in controlling lane position in the final lane-reduction segment. There were no other statistically reliable differences in mean lane deviation reflects the between conditions ($p > .05$). Appendix D provides the full ANOVA tables.

Force Right / Neutral Zone. Scenario 8 contained a knurled roadway marking a neutral zone and a rumble strip at the end of the passing zone to assist drivers in merging back to the left lane. A Welch test on lane deviation 1/10th-mile from the end of the 2-1 lane-reduction transition section (just after the 2 lane section ends) yielded marginally-reliable result [$W'(9, 118.097) = 1.680$, $p = 0.101$]. As the reader can see from Figure 13, this analysis is hampered by a great deal of variability at the end of the passing lane. To provide a more direct test, an unequal variance t-test was used to compare baseline to the force right condition. This suggests that the neutral zone condition does have some impact on moving drivers back to the left lane. Drivers were on average ~3 ft. closer to the left lane with the force right scenario compared to baseline [$t(57.9) = 2.217$, $p = 0.015$, $d = 0.572$, obs. power = 0.707]. In sum, the force-right/neutral zone had little consistent effect on driver behavior in our study.

Speed and Passing Efficiency. To assess the effects of our 10 scenarios on control of speed we computed the mean and standard deviations of the time-series measures of accelerator and brake pedal positions, and vehicle speed. The passing efficiency of our automated traffic was largely determined by two factors: 1) how quickly the participant moved into the right lane, and 2) how fast they drove once in the right lane. Our analysis of lane control above found that participants moved into the right hand lane in an equivalent amount of time across scenarios; therefore, differences in passing efficiency are influenced most by the speed of the participants vehicle: the slower the speed, the greater the efficiency. Vehicle speed was measured directly from the simulation, but we can also examine differences in how participants used the controls like the accelerator and brake pedal to regulate speed. However, because our participants only very rarely used the brake during the passing zones, our analysis

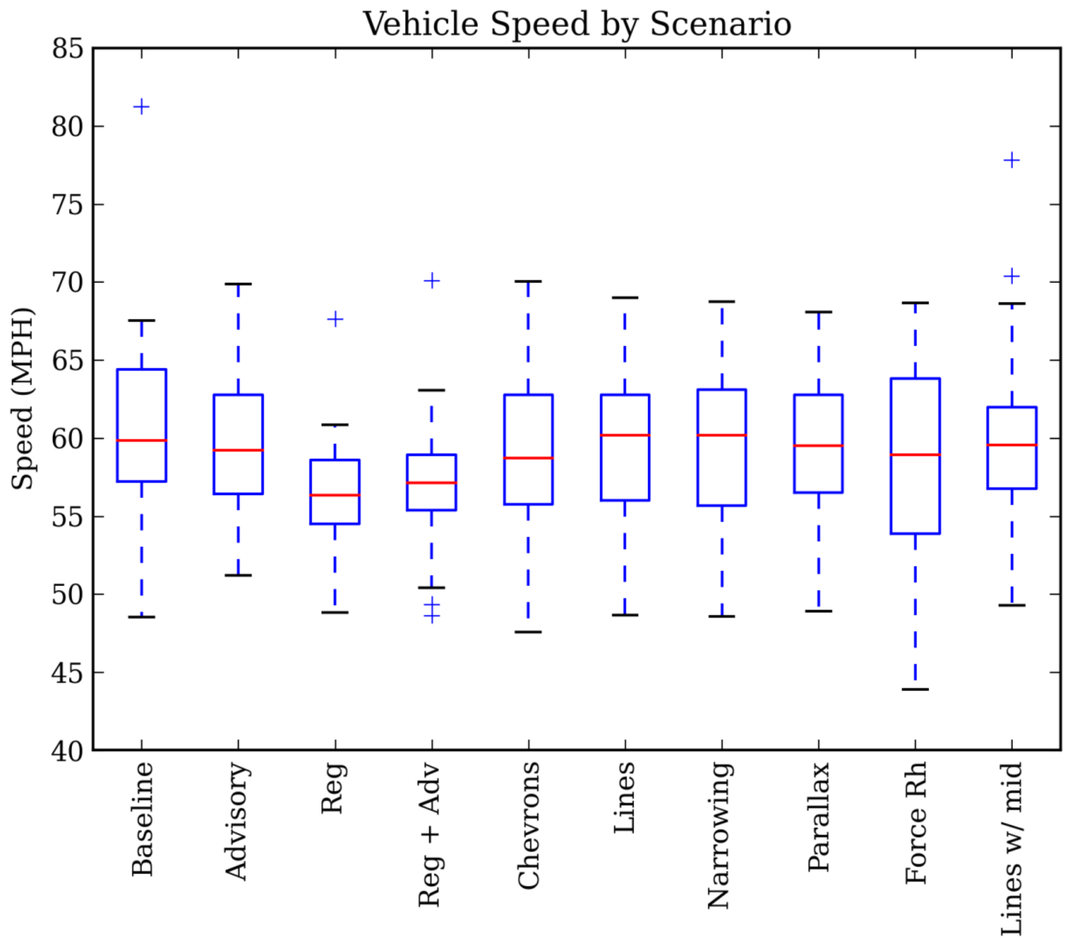


Figure 15. Mean Vehicle Speed by Scenario averaged over the 1-mile passing section. Box divisions represent 25, 50, and 75th percentiles. This figure represents the variability you would expect to see on the road across a sample of participants.

focused only on vehicle speed and accelerator position measures.

Speed and accelerator position measures for the one-mile length of two full-lanes. We analyzed the time-series of speed and accelerator position in a manner identical to that described for lane choice and control in the previous sections. This analysis examined the time series of accelerator position and vehicle speed over the one-mile, full-two-lane segment of the passing zone and ignored (for the time being) the 1/8 mile long diverging and merging transition zones.

Welch's test found reliable differences between scenarios only for the measure of mean vehicle speed, [$W'(9, 117.956) = 5.998$, $p < .05$]. The pattern of means can be seen in Figure 15. Pairwise comparisons show that the regulatory and regulatory + advisory scenarios carried most of the effect (see Table 3). The regulatory scenario was reliably different at $\alpha = 0.05$ from all other scenarios except the regulatory + advisory scenario. The regulatory + advisory scenario was reliably different (at $\alpha = 0.05$) from the baseline, lane narrowing, and lines with middle line scenarios. Compared to the baseline, drivers were ~6.5 mph slower over the 1-mile section (59.9 vs. 53.4 mph). The Welch's test and Games-Howell comparisons above found no other statistically reliable effects. However, we also analyzed the data using within-subjects confidence intervals, a somewhat less conservative, yet more visually intuitive approach championed by Loftus and Masson (1994).

Because our experiment measured every participant in every scenario—a *repeated measures* design—we can compare each participant's performance in the 9 test scenarios to their performance in the baseline scenario. This procedure allows each participant to act as his or her own control group and thereby removes between-subjects variability. The Loftus and Masson approach is based on using a repeated-measures analysis of variance (ANOVA) to pool error variance and determine a 95% confidence interval about the baseline condition. Scenario means falling outside this interval are then considered statistically reliable at $a < .05$.

Table 3. Multiple comparisons for speed over the 2-lane passing zone

WELCH'S ROBUST TEST OF EQUALITY OF MEANS

Statistic	df1	df2	P-value
5.998	9	117.956	6.806e-07

POSTHOC MULTIPLE COMPARISONS

Games-Howell: Table of Mean Differences

	0Base	1Advisory	2Reg	3Reg+Adv	4Chevrons	5Lines	6Narrowing	7Parallax	8ForceRh	9LinesWmid
0Base	0	2.115 (1.616) ns q(1.85,10,53.6)=0.900	6.513 (1.493) ** q(6.17,10,46.1)=0.003	5.684 (1.524) * q(5.27,10,48.3)=0.016	1.603 (1.662) ns q(1.36,10,55.4)=0.900	1.842 (1.718) ns q(1.52,10,56.9)=0.900	0.995 (1.643) ns q(0.86,10,54.7)=0.900	1.489 (1.681) ns q(1.25,10,56.0)=0.900	1.221 (1.765) ns q(0.98,10,57.6)=0.900	0.350 (1.709) ns q(0.29,10,56.7)=0.900
1Advisory	2.115 (1.616) ns q(1.85,10,53.6)=0.900	0	4.399 (1.217) * q(5.11,10,54.4)=0.021	3.569 (1.255) ns q(4.02,10,56.1)=0.147	-0.512 (1.419) ns q(0.51,10,57.7)=0.900	-0.273 (1.484) ns q(0.26,10,56.7)=0.900	-1.119 (1.397) ns q(1.13,10,57.9)=0.900	-0.626 (1.442) ns q(0.61,10,57.4)=0.900	-0.893 (1.539) ns q(0.82,10,55.5)=0.900	-1.764 (1.474) ns q(1.69,10,56.9)=0.900
2Reg	6.513 (1.493) ** q(6.17,10,46.1)=0.003	4.399 (1.217) * q(5.11,10,54.4)=0.021	0	-0.829 (1.092) ns q(1.07,10,57.7)=0.900	-4.911 (1.278) * q(5.44,10,52.4)=0.011	-4.671 (1.349) * q(4.90,10,50.1)=0.034	-5.518 (1.252) ** q(6.23,10,53.2)=0.002	-5.025 (1.302) * q(5.46,10,51.6)=0.011	-5.292 (1.409) * q(5.31,10,48.4)=0.015	-6.163 (1.338) ** q(6.51,10,50.5)=0.001
3Reg+Adv	5.684 (1.524) * q(5.27,10,48.3)=0.016	3.569 (1.255) ns q(4.02,10,56.1)=0.147	-0.829 (1.092) ns q(1.07,10,57.7)=0.900	0	-4.081 (1.313) + q(4.39,10,54.5)=0.081	-3.842 (1.383) ns q(3.93,10,52.4)=0.171	-4.689 (1.289) * q(5.15,10,55.2)=0.020	-4.195 (1.338) + q(4.44,10,53.7)=0.076	-4.463 (1.442) + q(4.38,10,50.6)=0.085	-5.334 (1.372) ** q(5.50,10,52.7)=0.010
4Chevrons	1.603 (1.662) ns q(1.36,10,55.4)=0.900	-0.512 (1.419) ns q(0.51,10,57.7)=0.900	-4.911 (1.278) * q(5.44,10,52.4)=0.011	-4.081 (1.313) + q(4.39,10,54.5)=0.081	0	0.239 (1.534) ns q(0.22,10,57.6)=0.900	-0.607 (1.449) ns q(0.59,10,57.9)=0.900	-0.114 (1.493) ns q(0.11,10,58.0)=0.900	-0.381 (1.587) ns q(0.34,10,56.9)=0.900	-1.253 (1.524) ns q(1.16,10,57.7)=0.900
5Lines	1.842 (1.718) ns q(1.52,10,56.9)=0.900	-0.273 (1.484) ns q(0.26,10,56.7)=0.900	-4.671 (1.349) * q(4.90,10,50.1)=0.034	-3.842 (1.383) ns q(3.93,10,52.4)=0.171	0.239 (1.534) ns q(0.22,10,57.6)=0.900	0	-0.847 (1.513) ns q(0.79,10,57.3)=0.900	-0.353 (1.555) ns q(0.32,10,57.8)=0.900	-0.621 (1.646) ns q(0.53,10,57.8)=0.900	-1.492 (1.585) ns q(1.33,10,58.0)=0.900
6Narrowing	0.995 (1.643) ns q(0.86,10,54.7)=0.900	-1.119 (1.397) ns q(1.13,10,57.9)=0.900	-5.518 (1.252) ** q(6.23,10,53.2)=0.002	-4.689 (1.289) * q(5.15,10,55.2)=0.020	-0.607 (1.449) ns q(0.59,10,57.9)=0.900	-0.847 (1.513) ns q(0.79,10,57.3)=0.900	0	0.493 (1.471) ns q(0.47,10,57.8)=0.900	0.226 (1.567) ns q(0.20,10,56.4)=0.900	-0.645 (1.503) ns q(0.61,10,57.4)=0.900
7Parallax	1.489 (1.681) ns q(1.25,10,56.0)=0.900	-0.626 (1.442) ns q(0.61,10,57.4)=0.900	-5.025 (1.302) * q(5.46,10,51.6)=0.011	-4.195 (1.338) + q(4.44,10,53.7)=0.076	-0.114 (1.493) ns q(0.11,10,58.0)=0.900	-0.353 (1.555) ns q(0.32,10,57.8)=0.900	0.493 (1.471) ns q(0.47,10,57.8)=0.900	0	-0.267 (1.607) ns q(0.24,10,57.3)=0.900	-1.138 (1.545) ns q(1.04,10,57.9)=0.900
8ForceRh	1.221 (1.765) ns q(0.98,10,57.6)=0.900	-0.893 (1.539) ns q(0.82,10,55.5)=0.900	-5.292 (1.409) * q(5.31,10,48.4)=0.015	-4.463 (1.442) + q(4.38,10,50.6)=0.085	-0.381 (1.587) ns q(0.34,10,56.9)=0.900	-0.621 (1.646) ns q(0.53,10,57.8)=0.900	0.226 (1.567) ns q(0.20,10,56.4)=0.900	-0.267 (1.607) ns q(0.24,10,57.3)=0.900	0	-0.871 (1.636) ns q(0.75,10,57.7)=0.900
9LinesWmid	0.350 (1.709) ns q(0.29,10,56.7)=0.900	-1.764 (1.474) ns q(1.69,10,56.9)=0.900	-6.163 (1.338) ** q(6.51,10,50.5)=0.001	-5.334 (1.372) ** q(5.50,10,52.7)=0.010	-1.253 (1.524) ns q(1.16,10,57.7)=0.900	-1.492 (1.585) ns q(1.33,10,58.0)=0.900	-0.645 (1.503) ns q(0.61,10,57.4)=0.900	-1.138 (1.545) ns q(1.04,10,57.9)=0.900	-0.871 (1.636) ns q(0.75,10,57.7)=0.900	0

+ p < .10, * p < .05, ** p < .01, *** p < .001

| Mean difference (standard error) |
| q(q-statistic, k, df') = p |

Figure 16 presents mean vehicle speeds for scenarios 1-9 normalized to each Figure 16

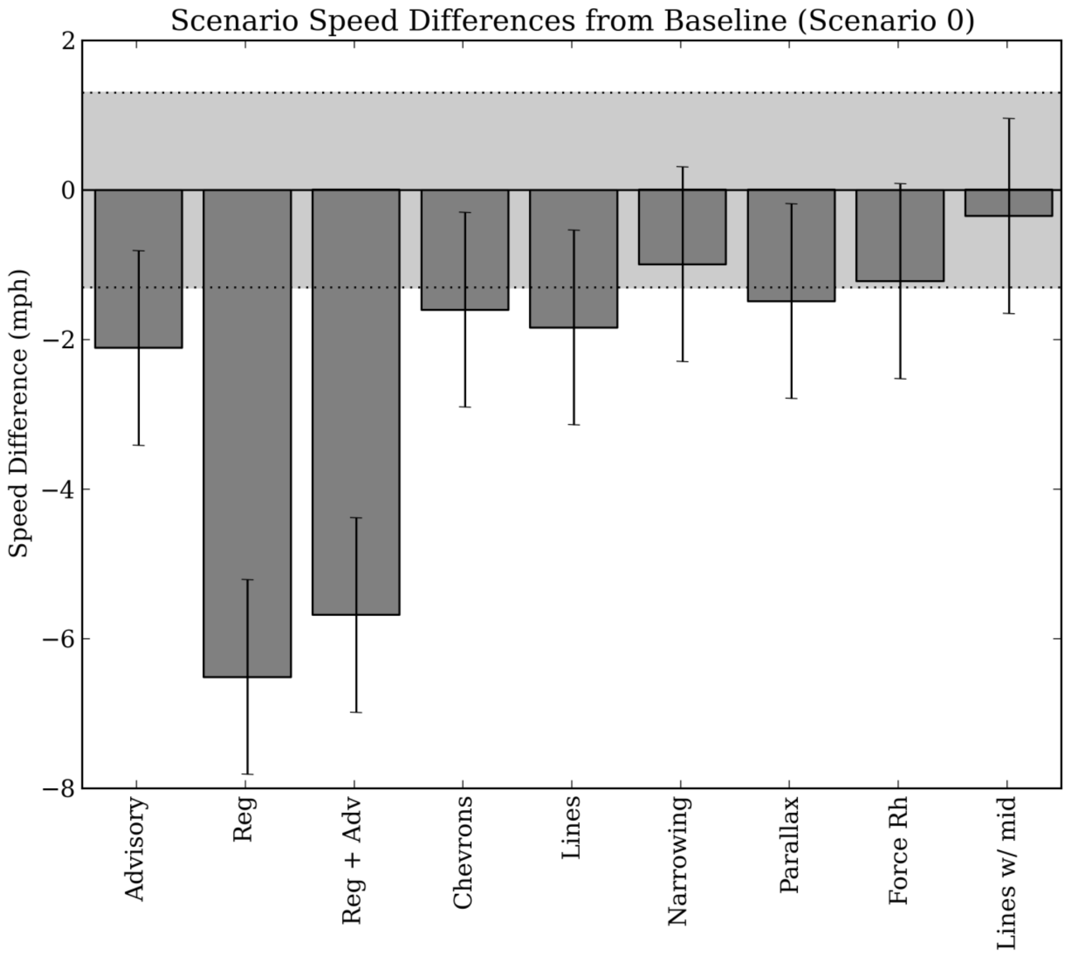


Figure 16. Speed differences normalized from baseline speed with error bars reflecting 95% confidence intervals after removing the between-subjects variability.

represents the participant's mean vehicle speed in the baseline scenario with 95% confidence intervals indicated on the plot as error bars. Means with error bars that fall outside of the light gray band are considered reliably different from baseline, and means whose error bars do not overlap are considered reliably different from one another.

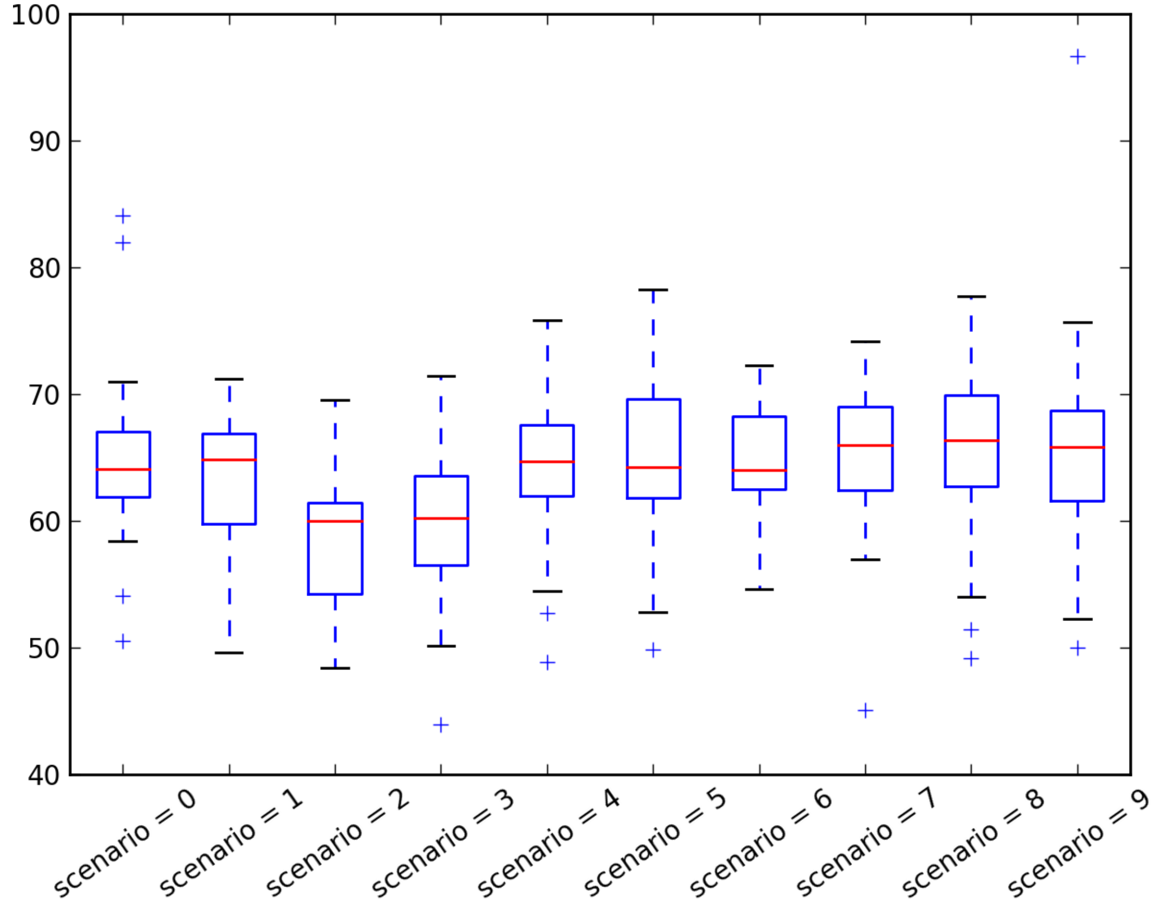


Figure 17. Boxplots representing the distributions of speed intercept estimates, a, across the scenarios.

Box divisions represent 25, 50, and 75th percentiles. The intercept for scenario 2– regulatory is reliably lower than all the intercepts except scenario 3 – regulatory + advisory ($p < .05$). All other intercepts are statistically equivalent ($p > .05$).

According to this analysis, six of the 9 test scenarios (non-baseline) reliably reduced the average vehicle speed over the one-mile full two-lane segment of the passing zone: scenario 1—advisory reduced speed by 2.2 mph; scenario 2—regulatory by 6.6 mph; scenario 3—regulatory + advisory by 5.5 mph; scenario 4—Chevrons by 1.6mph; scenario 5—transverse line by 1.8 mph; and scenario 7—parallax by 1.5 mph.

In effect, the data presented in Figure 15 depict the variability one would expect to see on the road across a sample of drivers, whereas the data presented in Figure 16 depict the reliability of the scenarios in effecting the speed control of each individual participant controlling for individual differences. Both approaches converge on a similar conclusion: scenarios including regulatory elements have the largest effect on reducing the speed of our participants, but the use of chevrons, transverse lines, or parallax should also be expected to have a reliable, though smaller effect on speed control.

To more precisely examine how participants controlled vehicle speed over the 1-mile passing zone, vehicle speed was linearly regressed on distance and the effect of scenario on the intercept and slope parameters was assessed using the Welch and Games-Howell procedures. (Regressing on distance, rather than time, prevents slow speed segments of data from carrying more weight in the model fitting.) Pairwise multiple comparisons showed that the speed intercept for the regulatory scenario 2 was reliably lower than for all other scenarios except the regulatory + advisory scenario 3 (see Figure 17). This result is consistent with participants reducing speed for the regulatory scenario 2 either before entering or very early in the passing zone. Further, the estimated slope parameters were not reliably different across the scenarios ($p > .05$), suggesting that the rate of deceleration was statistically equivalent across the conditions. When taken together, these results suggest an important conclusion: regulatory signage has its greatest impact in reducing speed when placed before or early in the passing zone.

Speed and accelerator position measures by segment and scenario. To assess differences in control of speed across the different entire passing zone, including both the 1/8th-mile lane-addition transition and the 1/8th-mile lane-reduction, we used 3 x 10 factorial repeated-measures analyses of variance (ANOVAs). These analyses compared the means and standard deviations of accelerator position and speed for each factorial combination of the 3 passing zone segments (first 1/8 mile lane-addition transition section, next one-mile long full two-lane section, and last 1/8 mile lane-reduction transition) and the 10 scenarios enumerated in Table 1. All main effects and interactions were interpreted using Greenhouse and Geisser's correction for violations of sphericity. Appendix D provides the full ANOVA tables.

The analysis of mean accelerator position revealed a reliable segment by scenario interaction [$F(18, 522) = 2.106$, $p = 0.033$, $\eta^2_G = 0.044$, $\varepsilon_{GG} = 0.468$, observed-power = 0.085]. For all scenarios except Scenario 2: Regulatory, the mean accelerator position did not reliably differ across the passing zone segments (grand mean = .425 in a range of 0 to 1). The regulatory Scenario 2 segment 1, however, had a mean accelerator position of .359 as compared to the .429 marginal mean for segment 1. This result suggests that for the lane-addition transition, participants spent more time coasting in the regulatory condition compared to the other conditions. We also found a significant main effect of segment on accelerator position standard deviation (SD), $F(2, 58) = 104.145$, $p < 0.001$, $\eta^2_G = 0.654$, $\varepsilon_{GG} = 0.338$, observed-power = 1.000. Least variability occurred in the lane-addition segment 1 ($\sigma = .047$), greatest variability in the full 2-lane segment 2 ($\sigma = .142$), and moderate variability in the lane-reduction segment 3 ($\sigma = .121$).

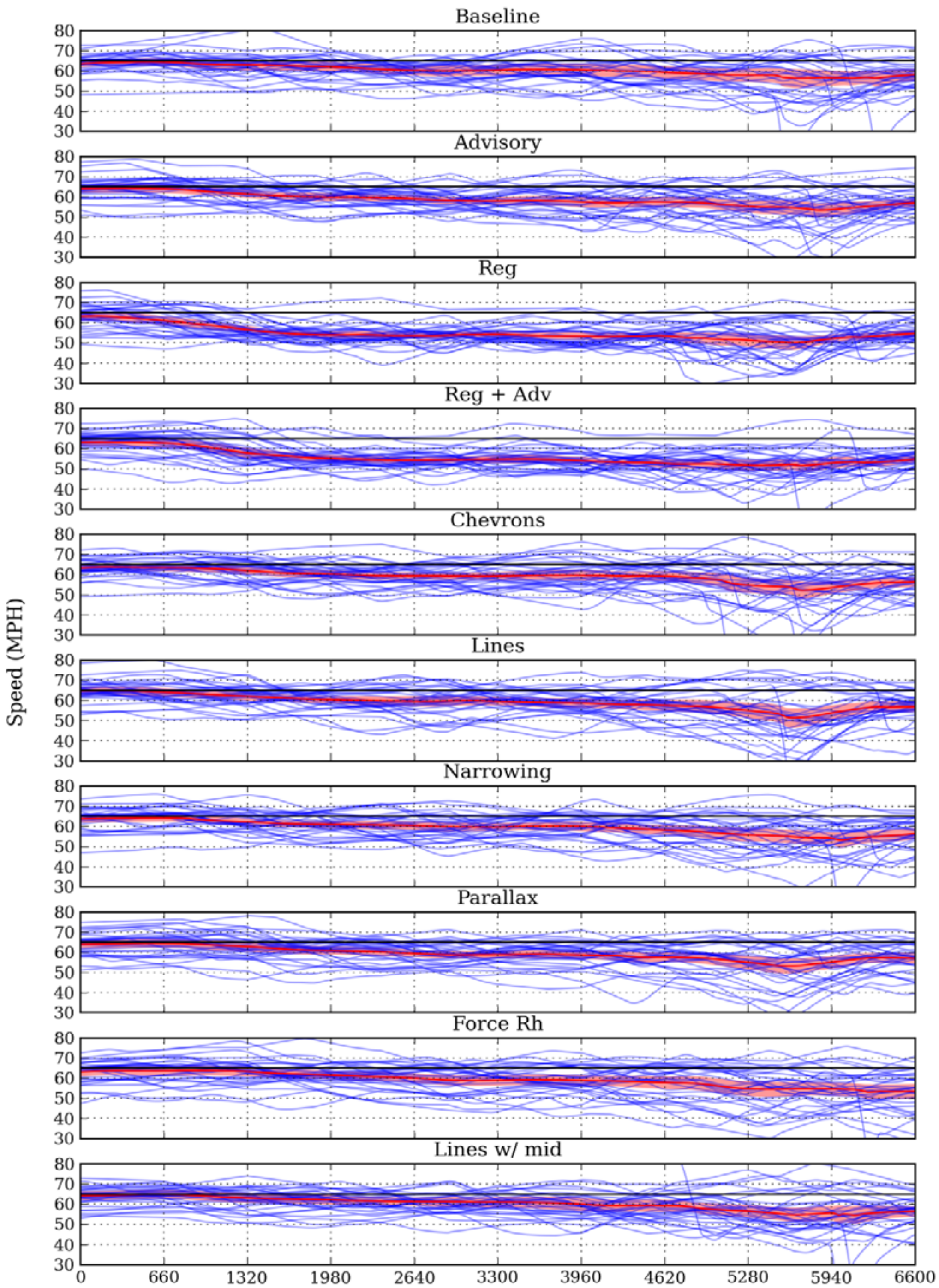


Figure 18. Vehicle speeds as functions of distance segregated by scenario.

Distance axes are in feet and extend from the beginning of 1-to-2 lane-addition transition through the end of the 2-to-1 lane-reduction transition. The 1-mile segment extends from 660 to 5940 feet. For each panel the blue traces represent individual participants. The red trace represents the ensemble average over distance. The red fills represents 95% confidence intervals on the ensemble averages.

The analysis of mean vehicle speed found a segment main effect, with participants driving more slowly in the lane-reduction transition segment (5940-6600 ft. on the abscissa of Figure 18, μ = 55.59 mph) as compared to the full 2-lane segment (660-5940 ft. on the abscissa of Figure 18, μ = 57.7 mph), and the fastest speeds occurring in the lane-addition transition segment (0-660 ft. on the abscissa of Figure 18, μ = 63.89 mph), $F(2, 58) = 102.679$, $p < 0.001$, $\eta^2_G = 0.321$, $\varepsilon_{GG} = 0.550$, observed-power = 1.000.

We also found a significant interaction of segment and scenario on mean vehicle speed [$F(18, 522) = 1.991$, $p = 0.043$, $\eta^2_G = 0.016$, $\varepsilon_{GG} = .481$, observed-power = 0.083]. This interaction reflects two deviations from the segment main effect across the 10 scenarios:

a) a greater reduction in vehicle speed during the full 2-lane segment of the passing zone as compared to the transition segments for the regulatory Scenario 2 and the regulatory+advisory Scenario 3, and

b) reliably slower speeds in the lane-reduction segment as compared to the full 2-lane segment, for scenarios 6, 8 and 9 (lane narrowing, force-right, and transverse lines with middle segment, respectively).

The analysis of the standard deviation (SD) of vehicle speed shows greatest variability in the full 2-lane segment (σ = 4.97 mph), moderate variability in to the lane-reduction transition segment (σ = 2.28 mph) and least variability in the lane-addition transition segment (σ = 0.88 mph), $F(2, 58) = 288.673$, $p < 0.001$, $\eta^2_G = 0.963$, $\varepsilon_{GG} = 0.525$, observed-power = 1.000. As with accelerator position SD, vehicle speed SD is confounded by the fact that the wind disturbance

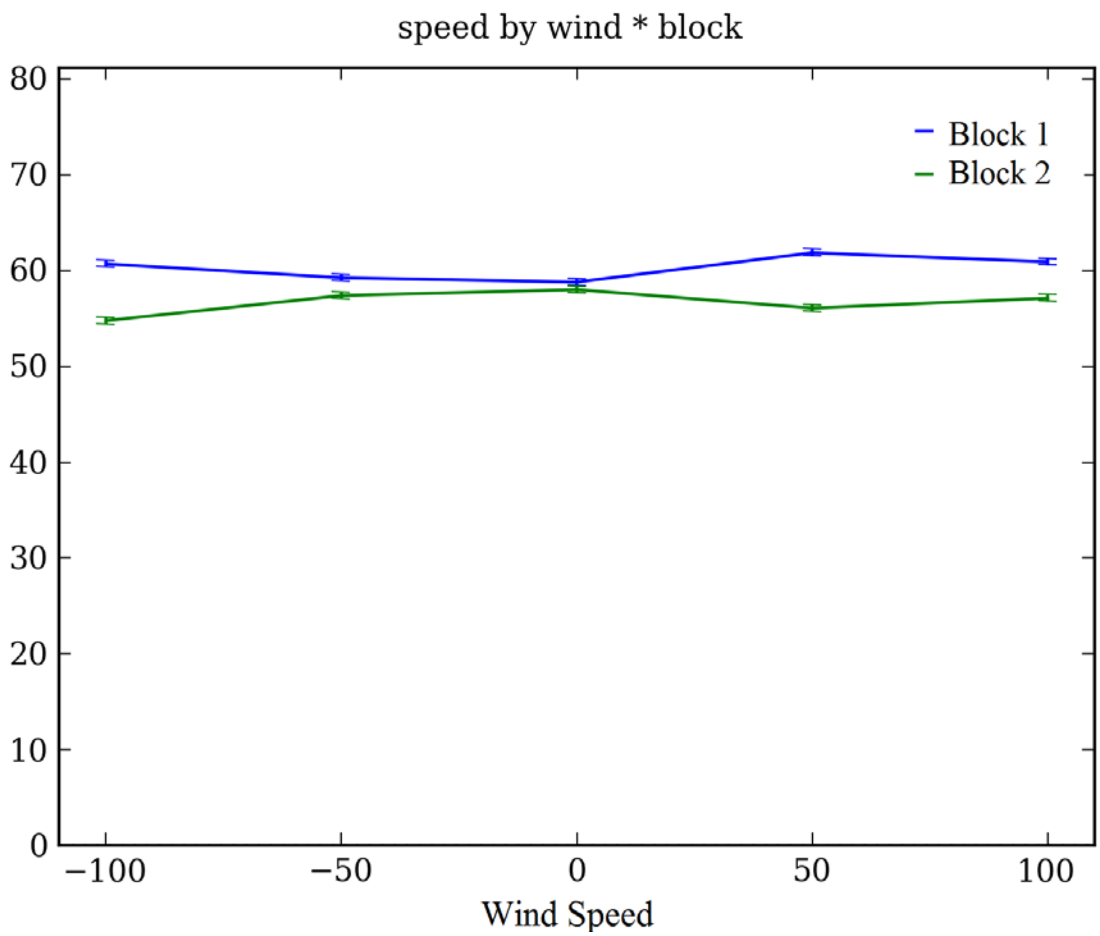


Figure 19. Wind Disturbance by block interaction. Error bars reflect 95% confidence intervals.

was only present throughout the full 2-lane segment. Even so, speed is significantly more variable the lane addition transition segment than in the lane reduction transition segment.

Effect of simulated wind disturbance on speed control. We used a 3-factor, 5 x 2 x 10, ANOVA to assess how the simulated wind disturbance influenced speed control through the full 2-lane segment of the passing zone with the five wind speed conditions (-100,-50,0, 50, and 100 mph as defined by the NADS MiniSim Driving Simulator), two-level repetition factor (block), and 10 scenarios as the factors. As expected, the wind disturbance affected vehicle speed [*F*(4,

116) = 10.990, p < 0.001, η^2_G = 0.005, ε_{GG} = .611, observed-power = 1.000], but the size of the effect was not dramatic. With the 100 mph tail-wind participants were only 1.28 mph faster than with the 100 mph head-wind. A reliable main effect of block on speed control was also found [F(1, 29) = 71.147, p < 0.001, η^2_G = 0.069, observed-power = 1.000], as well as a significant wind by block interaction [F(4, 116) = 88.470, p < 0.001, η^2_G = 0.022, ε_{GG} = .369, observed-power = 1.000], though the significance of this interaction is not well understood. The interaction with 95% confidence intervals is in Figure 19.

In regard to scenario, the ANOVA replicates the previous Welch test on vehicle speed with a main effect of wind speed [F(9, 261) = 12.615, p < 0.001, η^2_G = 0.092, ε_{GG} = .366, observed-power = 1.000]. No reliable interactions with scenario were found suggesting that the wind disturbance functioned as intended without any measurable unintended side effects. For a full ANOVA summary see Table 4.

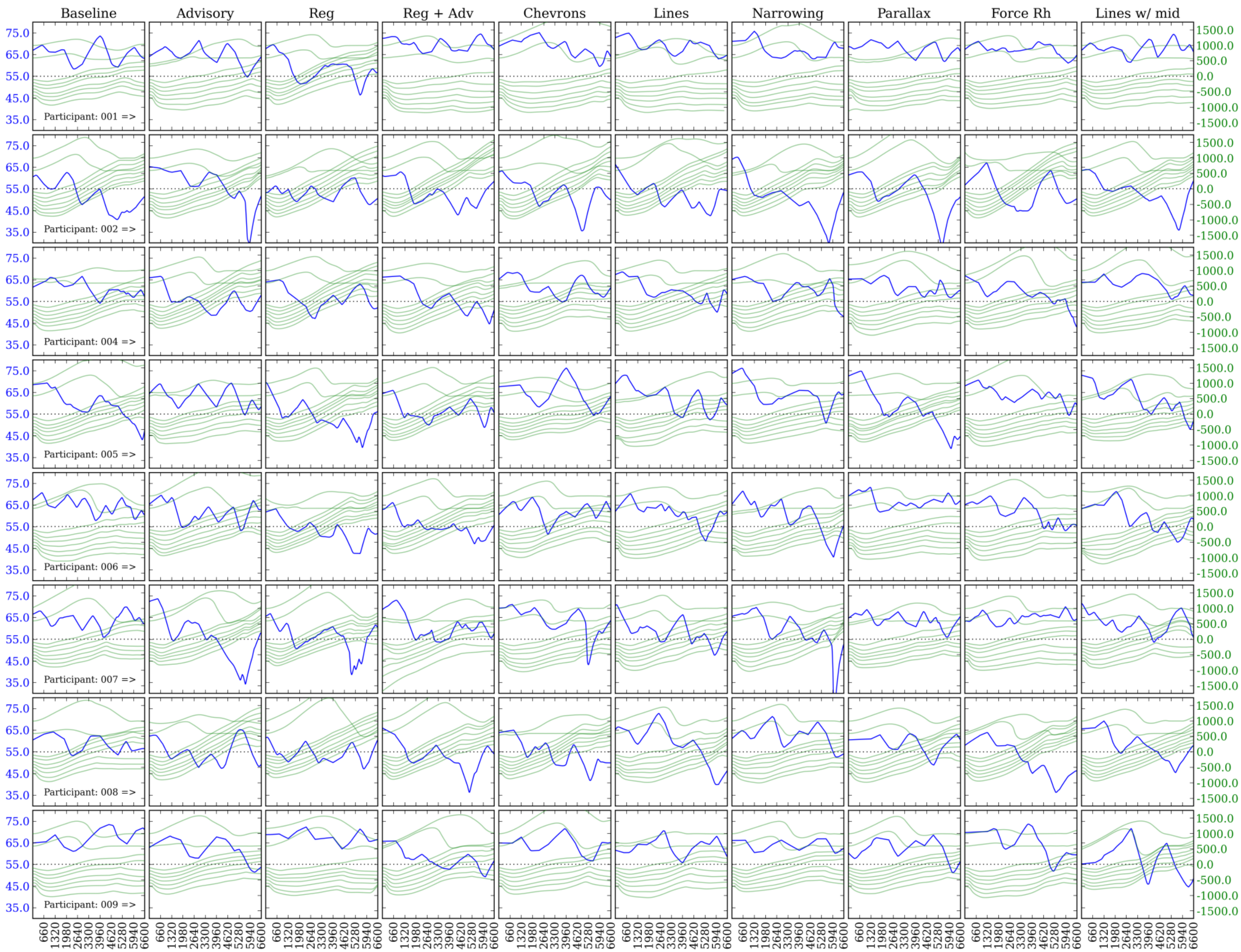
Table 4. Wind x Block x Scenario ANOVA Summary Table

speed ~ block * wind * scenario

TESTS OF WITHIN SUBJECTS EFFECTS

Measure: speed

Source		Type III SS	eps	df	MS	F	Sig.	et2_G	Obs.	SE	95% CI	lambda	Obs. Power
block	Sphericity Assumed	9877.063	-	1	9877.063	71.147	2.699e-09	0.069	1500	0.317	0.622	3680.036	1
	Greenhouse-Geisser	9877.063	1	1	9877.063	71.147	2.699e-09	0.069	1500	0.317	0.622	3680.036	1
Error(block)	Sphericity Assumed	4025.937	-	29	138.825								
	Greenhouse-Geisser	4025.937	1	29	138.825								
wind	Sphericity Assumed	667.451	-	4	166.863	10.990	1.364e-07	0.005	600	0.161	0.315	227.378	1
	Greenhouse-Geisser	667.451	0.611	2.444	273.096	10.990	2.098e-05	0.005	600	0.161	0.315	227.378	1
Error(wind)	Sphericity Assumed	1761.256	-	116	15.183								
	Greenhouse-Geisser	1761.256	0.611	70.876	24.850								
scenario	Sphericity Assumed	13101.570	-	9	1455.730	12.615	1.284e-16	0.092	300	0.623	1.221	130.499	1
	Greenhouse-Geisser	13101.570	0.366	3.292	3979.311	12.615	2.116e-07	0.092	300	0.623	1.221	130.499	1.000
Error(scenario)	Sphericity Assumed	30118.756	-	261	115.398								
	Greenhouse-Geisser	30118.756	0.366	95.480	315.445								
block * wind	Sphericity Assumed	3162.038	-	4	790.510	88.470	2.591e-34	0.022	300	0.174	0.342	915.202	1
	Greenhouse-Geisser	3162.038	0.369	1.476	2141.816	88.470	3.811e-14	0.022	300	0.174	0.342	915.202	1
Error(block * wind)	Sphericity Assumed	1036.505	-	116	8.935								
	Greenhouse-Geisser	1036.505	0.369	42.814	24.210								
block * scenario	Sphericity Assumed	203.951	-	9	22.661	0.512	0.865	0.001	150	0.546	1.070	2.649	0.152
	Greenhouse-Geisser	203.951	0.645	5.804	35.139	0.512	0.793	0.001	150	0.546	1.070	2.649	0.128
Error(block * scenario)	Sphericity Assumed	11550.115	-	261	44.253								
	Greenhouse-Geisser	11550.115	0.645	168.318	68.621								
wind * scenario	Sphericity Assumed	386.314	-	36	10.731	0.722	0.888	0.003	60	0.498	0.977	1.493	0.072
	Greenhouse-Geisser	386.314	0.343	12.339	31.309	0.722	0.734	0.003	60	0.498	0.977	1.493	0.063
Error(wind * scenario)	Sphericity Assumed	15521.262	-	1044	14.867								
	Greenhouse-Geisser	15521.262	0.343	357.822	43.377								
block * wind * scenario	Sphericity Assumed	632.181	-	36	17.561	0.797	0.798	0.004	30	0.858	1.681	0.825	0.062
	Greenhouse-Geisser	632.181	0.310	11.148	56.708	0.797	0.644	0.004	30	0.858	1.681	0.825	0.057
Error(block * wind * scenario)	Sphericity Assumed	22991.806	-	1044	22.023								
	Greenhouse-Geisser	22991.806	0.310	323.290	71.118								


Baseline
Advisory
Reg
Reg + Adv
Chevrons
Lines
Narrowing
Parallax
Force Rh
Lines w/ mid
Participant: 001 =>
Participant: 002 =>
Participant: 004 =>
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Participant: 007 =>
Participant: 008 =>
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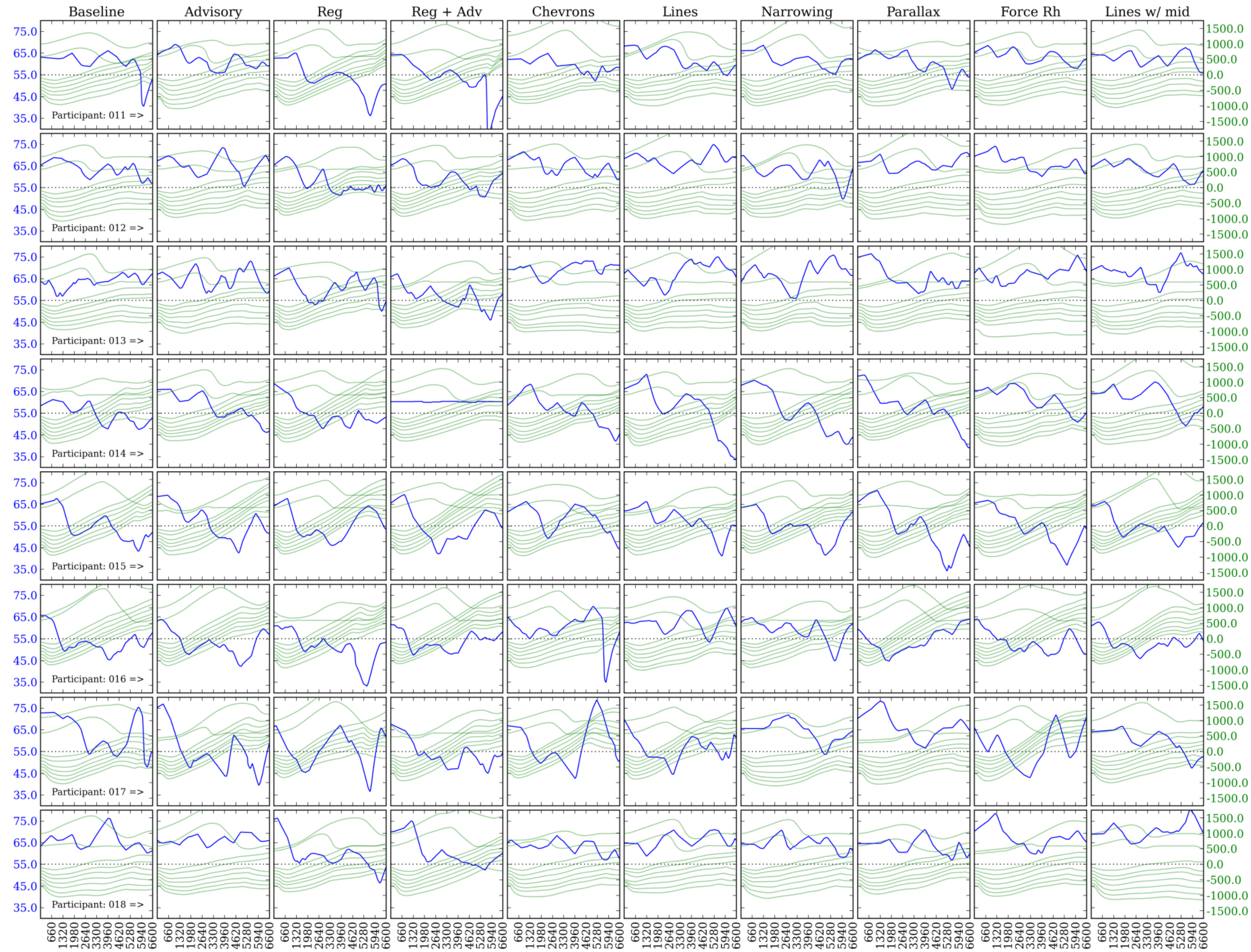

Baseline
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Participant: 014 =>
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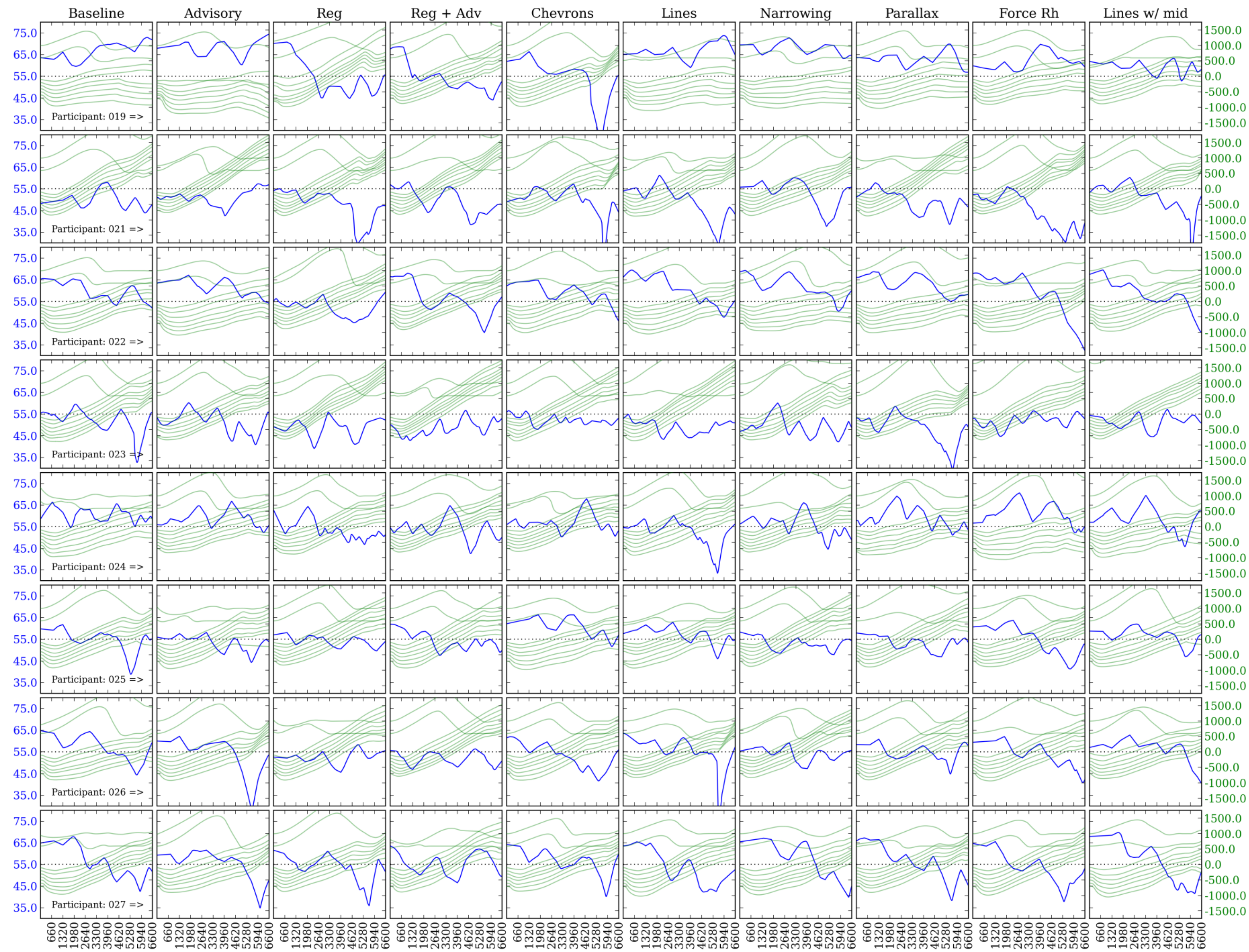

Baseline
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Chevrons
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Narrowing
Parallax
Force Rh
Lines w/ mid
Participant: 019 =>
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Participant: 022 =>
Participant: 023 =>
Participant: 024 =>
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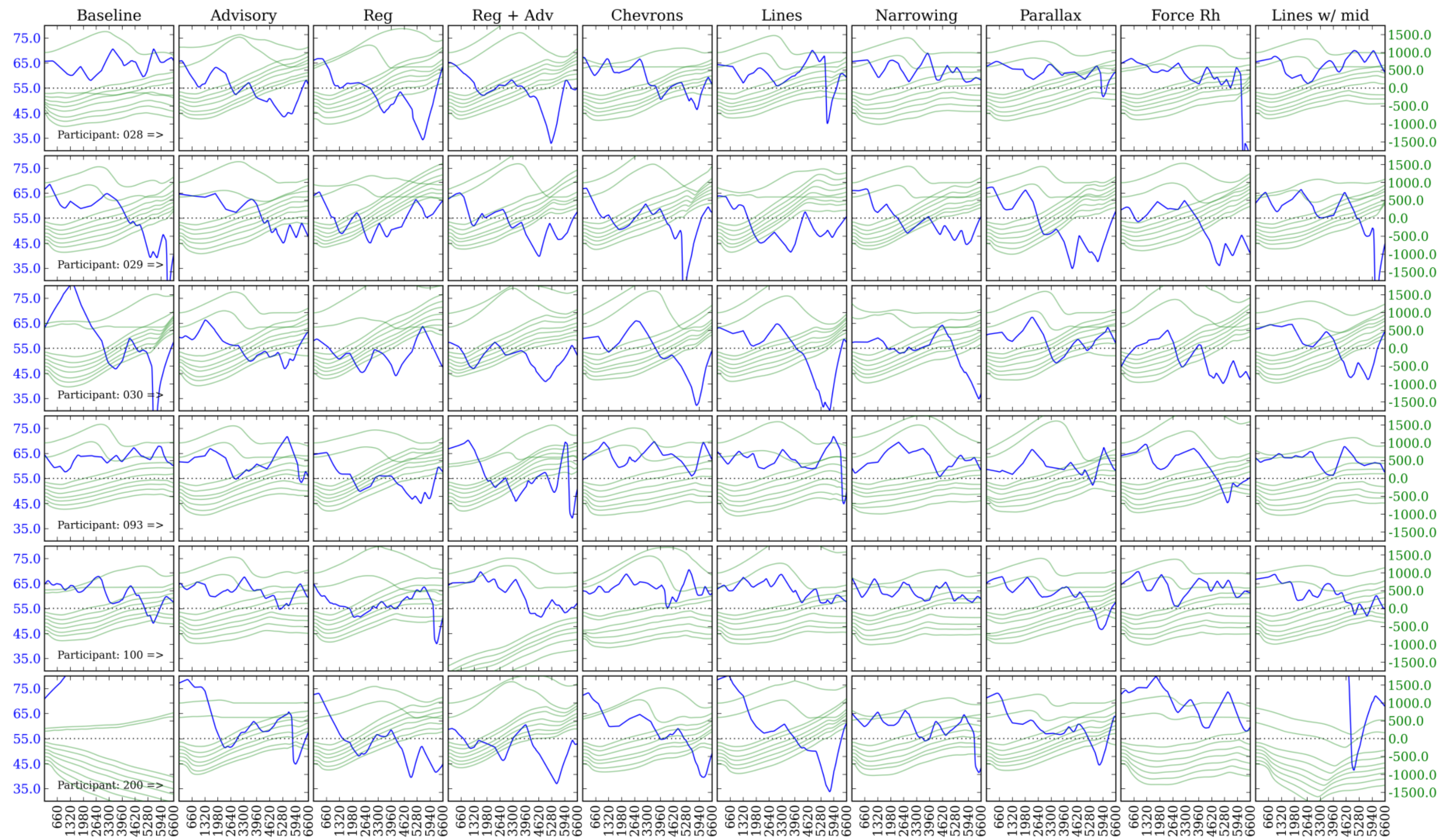


Figure 20 Each subplot represents a single passing lane event.

Participants are grouped as rows and the scenarios are grouped as columns. The blue trace represents the participant's speed over the 1.25 mile passing zone. The relative distances (in feet) of the other vehicles are depicted as the green traces. Negative relative distances indicate that the vehicle is behind the driver. Positive relative distances indicate the vehicle is in front of the driver.

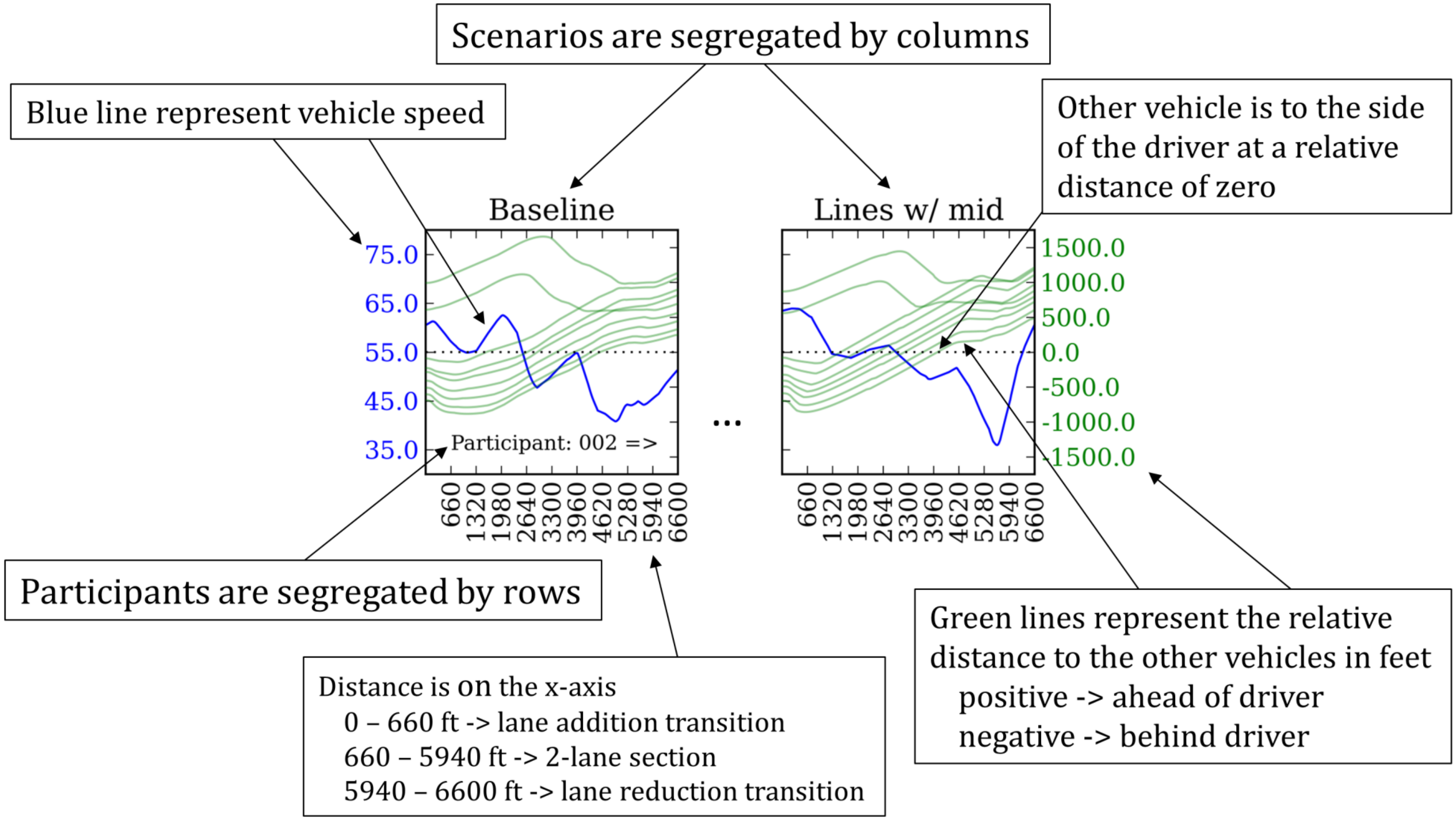


Figure 21 Annotated guide to deciphering Figure 20.

Passing Efficiency and Safety of AI controlled vehicles. The analyses of vehicle speeds suggest that the regulatory conditions resulted in slower speeds. Here we examine whether the speed reductions enabled simulated vehicles to more efficiently and safely pass the driver.

For each passing lane, the participant was accompanied by a platoon of nine or ten other vehicles dynamically controlled by the NADS MiniSim. For the majority of the scenarios, two vehicles would lead the participant into the passing lane. Passing performance was quantified by counting the number of cars that passed the vehicle during the 1-mile 2-full lane segment. Based on this metric, Welch's test found that passing efficiency was not equivalent across the 10 scenarios [W' (9, 117.995) = 5.128, $p < .001$]: significantly more vehicles were able to pass during the regulatory scenario 2 as compared to baseline and visual cue conditions. Indeed, passing performance reached the optimal ceiling-- all 7 trailing vehicles were allowed to pass—with the regulatory scenario 2 for 22 of the 30 participants.

We used *average time margin* at the start of the lane-reduction segment as our measure of safety in passing. For each scenario and participant, we determined average time margin by computing the mean of times at which each vehicle in the platoon of passing vehicles entered the lane-reduction segment and subtracted this mean time from the time when the participant's vehicle entered the lane-reduction segment. Positive average time margins occurred when a participant entered the lane-reduction at a later time than the average, negative values indicate the participant entered at a time ahead of the average. The Welch test indicated a reliable effect of scenario on average time margin [W' (9, 118.076) = 4.085, $p < .001$]. Post-hoc tests indicated that the regulatory scenario differed significantly from the baseline scenario 0 and scenarios 4, 6, 7, 8, and 9. The moment-to-moment interaction with the other vehicles and vehicle speeds is displayed in Figure 20, whose legend can be viewed in Figure 21.

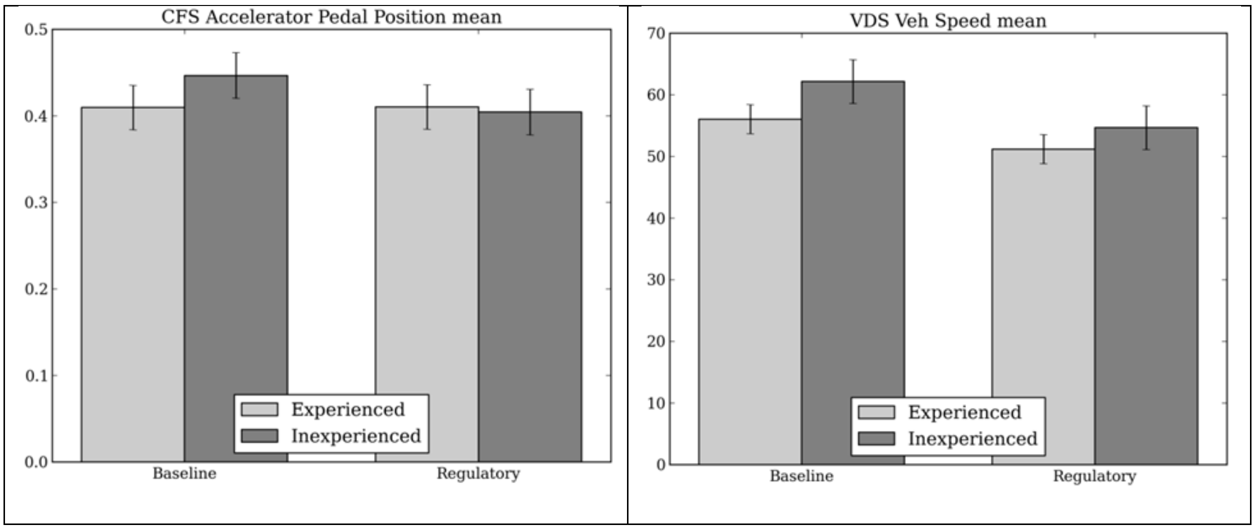


Figure 22. Accelerator position and mean vehicle speed as functions of driving experience for the baseline and regulatory scenarios. Error bars reflect 95% confidence intervals calculated according to Moray (2008).

Our analysis found a reliable effect of scenario on mean vehicle speed [$Q(1.08) = 7.389$, $p = 0.009$, obs. power = 0.889, already discussed above] and a marginally reliable effect of experience [$Q(1.08) = 4.011$, $p = 0.051$, obs. power = 0.780]. According to this effect, inexperienced drivers demonstrated greater changes in driving behavior. Interpreted with the vehicle speed trend it suggests that experienced drivers are slower regardless of the scenario (see Figure 22).

Summary & Conclusions of Experiment 1

The lane choice and deviation data showed that our instructions and following traffic pressure were successful in inducing our RV-towing drivers to reliably move into the right lane of the passing zone during the lane-addition transition (99% of the time). This result was critical, since the regulations, advisories, and passive interventions for speed were specifically designed to affect drivers in the right lane only. Because our drivers moved to the right lane so reliably we are able to interpret the effects of the different scenarios on speed control. Our primary result was an approximately 5-6 mph average reduction in speed for the regulatory scenario 2 and regulatory + advisory scenario 3 as compared to the baseline scenario. Importantly, these scenarios had their greatest effect in reducing speed during the initial entry into the passing zone, which suggests that locating regulatory and advisory signs early in the passing zone or before it may optimize their impact. Some of the passive speed interventions (e.g., Chevrons, lane narrowing) also reliably reduced speed, but only by 1-2 mph.

Because drivers were so consistent in moving to the right lane during the lane addition, we found that passing efficiency mirrored the speed results. The regulatory and regulatory + advisory scenarios induced drivers in the right lane to drive more slowly, so more vehicles were able to pass in these conditions. There was also a greater time gap between the passing vehicles and the participant's vehicle at the beginning of the lane reduction segment, suggesting a safer passing environment for these scenarios.

In addition, it does appear that experience mitigates the speed reduction effects of the regulatory and regulatory + advisory scenarios. More experienced drivers (> 15 years since licensing) drive more slowly overall and have less reduction in speed than less experienced drivers, who drive more quickly overall and show greater reductions in speed for these scenarios. This result suggests that the regulatory and regulatory + advisory scenarios may be particularly effective in reducing speed for less experienced drivers.

In sum, the regulatory and regulatory + advisory scenarios appear create the greatest right-lane speed reductions, particularly for less-experienced RV-towing drivers. Passing efficiency should therefore increase for these scenarios, but only if the speed reduction occurs only for right-lane drivers. Our next experiment sought to measure the influence of these different scenarios on non-RV-towing drivers in the left lane to assess whether the speed reduction is specific to only the right lane as intended.

CHAPTER 4: EXPERIMENT 2 NON-TOWING DRIVERS

We designed Experiment 2 to assess the effects of our 10 passing lane scenarios on the behavior of drivers using the left lane. This experiment had two aims: 1) to examine whether the regulations, advisories, and lane markings designed to affect right-lane drivers lane also affected drivers in the left lane—an undesirable result, since it would reduce the efficiency of the passing lanes—and 2) to examine the influence of right-lane vehicle size on passing behavior.

Method

Participants. Twenty-three participants with valid driver's licenses were tested for this experiment. Three participants failed to complete the experiment due to motion sickness and were excluded from the analysis. Fourteen students from the University of Idaho participated and were given class credit for their participation. We recruited the remaining six participants using an online advertisement and compensated each of them $30 for their participation. All participants wore corrective lenses if they were required to wear them while driving. Participants had an average age of 25.1 years, ranging from age 19 to 47, with an average of 9.2 years of driving experience.

Stimuli. We designed traffic in Experiment 2 to induce pressure for participants to pass other vehicles. In each inter-passing zone stretch of highway a new set of 9 vehicles was created out of sight both ahead and behind the participant's vehicle. Seven leading vehicles were scripted to appear ahead of the participant's vehicle and drive 45 mph until the participant caught up to them, at which point the vehicles maintained a specific gap in front of the driver with the closest car being 200 feet ahead, and all other cars increasing in 100 foot increments, with the furthest car being 800 feet ahead.

At the start of each passing zone, these vehicles turned on their right-turn signals and pulled into the right-hand lane maintaining a constant speed of 65 mph, except for the regulatory scenarios where the vehicles maintained a speed of 55 mph. Two following cars were scripted to maintain distances of 600 and 1000 feet behind the participant's vehicle until it exited the passing zone, at which point these vehicles pulled to the side of the highway. To discourage participants from driving extremely fast, simulated police sirens sounded whenever their speed exceeded 85 mph.

To examine whether vehicle size influences passing behavior, the third vehicle ahead of the driver, or fifth in the platoon of seven vehicles counting from the front, was either a small sedan or a large semi-truck while the other six vehicles were always small sedans. We chose to manipulate the third vehicle ahead of the driver based on these assumptions: a) the platoon of vehicles in the right-lane would be driving 65 mph, b) most participants would maintain a speed of 72-73 mph while passing. This differential of 7-8 mph at 72-73 mph results in the passing vehicle gaining about 300 feet on the platoon of right-lane vehicles over the first half- mile stretch of the passing zone, making the third vehicle ahead (fifth in the platoon of seven)—located approximately 400 ft. ahead of the driver at the entrance to the passing zone—the likeliest object of a passing decision at the mid-point of the passing zone. The location of the semi-truck relative to the platoon of vehicles was adjusted backwards such that its front end was the same distance ahead of the driver as the front end of the sedan at the time the driver entered the passing zone. Because the semi-truck was 45 ft. longer than the sedan, this reduced the gap between the second and third vehicles by approximately 45 feet.

Procedure. We instructed participants to imagine they were heading home from a recreational weekend in the Alaskan countryside and—importantly—that they were in a hurry to get home. In addition, we instructed them to obey traffic regulations, advisories, and etiquette in a manner they normally would while driving in a hurry. The full instructions are listed in Appendix C. The entire experimental session lasted 90 minutes.

Results

We designed the instructions, task, and simulated traffic in this experiment to induce participants to use the left lane of the passing zones to pass some or all of the platoon of seven leading vehicles. The first section of our results presents evidence that this design succeeded in inducing these behaviors in our sample of participants. The second part of this section presents results that address whether the different passing zone scenarios affected the speed of drivers passing in the left hand lane. For maximum passing efficiency, the scenarios that reduced speed in the right lane should not affect drivers in the left lane, thereby maximizing the speed differential between the two lanes of traffic. The last section of the results addresses the manipulation of vehicle size (passenger car vs. semi-truck) on driver behavior while passing.

Lane Choice. We did not explicitly instruct participants to use the left lane and pass the leading vehicles, but rather implicitly encouraged participants to use the left lane by placing slower moving vehicles ahead of them and providing the instructions that they were "in a hurry to get home" and driving a sedan (rather than an RV). Because we aimed to examine whether our different scenarios affected left-lane drivers, we hoped these experimental operations

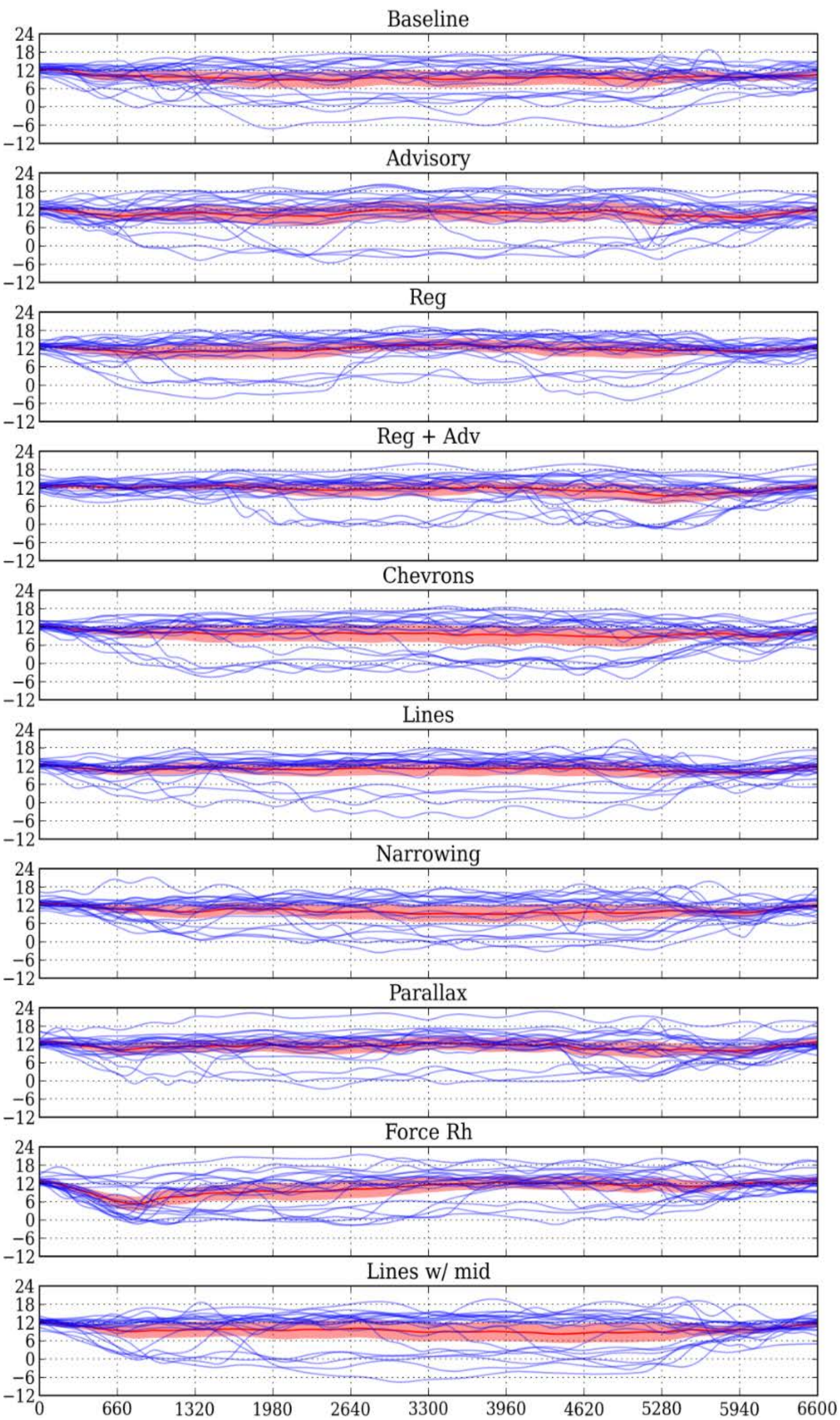


Figure 23 Vehicle lane deviation in feet from the center of the right lane as functions of distance for each scenario.

would induce our drivers to choose to use the left hand lane and pass at least some of the vehicles ahead of them. It appears these operations worked: Figure 23 shows that participants overwhelmingly preferred the left lane. Across all the scenarios, drivers occupied the left lane approximately 82% and there were no reliable differences in this percentage across scenarios ($p > .05$). Further, we found no reliable differences on mean lane deviation or steering wheel angle ($p > .05$), suggesting that the scenarios did not differentially affect lane choice or steering control.

In figure 23, the center of the left lane corresponds to 12 feet on the y-axis. The distance axis extends from the beginning of 1-to-2 lane-addition transition through the end of the 2-to-1 lane-reduction transition. The 1-mile full-two-lane segment extends from 660 to 5940 ft. For each panel, the blue traces represent data from individual participants. The bright red trace represents the ensemble average. The red fills represents 95% confidence intervals on the ensemble averages.

Scenario 8 incorporated a knurled force right pavement marking at the beginning of the passing lane. To examine whether this force right marking affected behavior we examined lane deviation at 664 ft. from the beginning of the passing zone and found a reliable effect of scenario [W'(9, 77.084) =3.161, p = .003]. The effect of the force right marking is apparent the 9th pane of Figure 23. Perhaps because of the novelty of the stimuli roughly 25% (5 of 20) participants did not abide by the pavement marking and drove directly into the left lane of the passing zone.

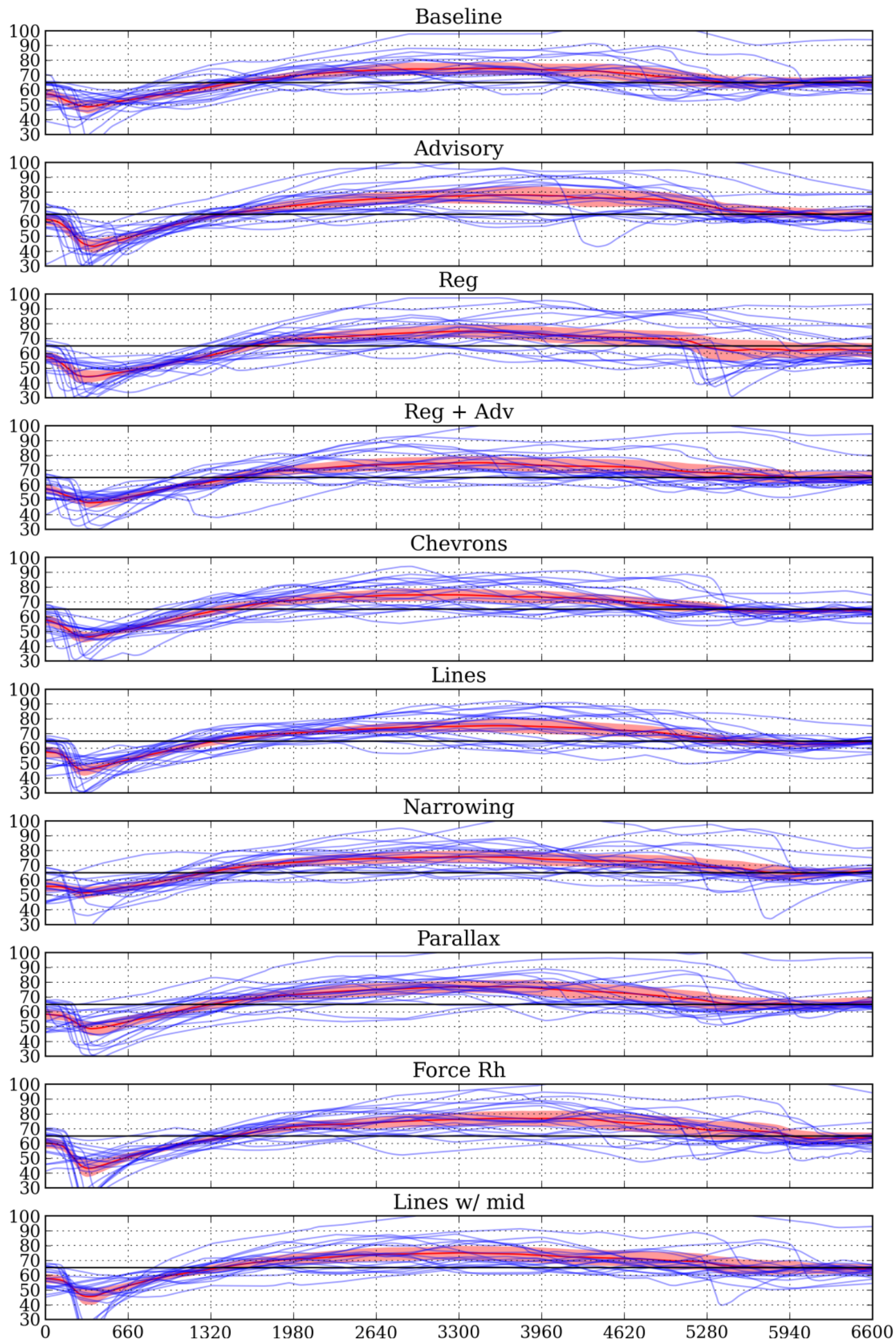


Figure 24 Vehicle speeds as functions of distance segregated by scenario.

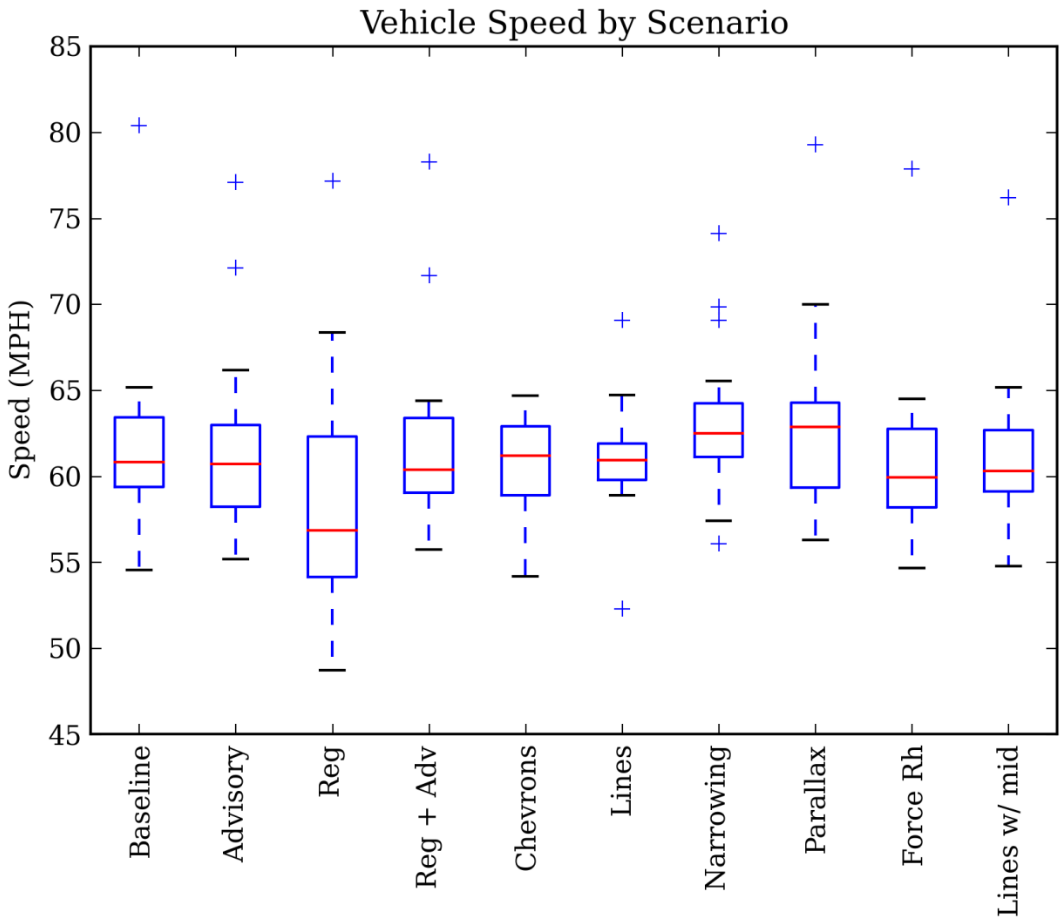


Figure 25 Mean Vehicle Speed by Scenario averaged over the 1-mile passing section. Box divisions represent 25, 50, and 75th percentiles.

Speed and Passing Efficiency. Similar to Experiment 1, to assess the effects of our 10 scenarios on control of speed, we computed the mean and standard deviations of the time-series measures of accelerator pedal position and vehicle speed. As with Experiment 1, brake pedal force data was recorded but was used so infrequently analyzing the variance about the means was not possible. Passing efficiency was determined by counting the number of cars passed for each condition. Figure 24 shows the vehicle speeds over the entire length of the passing zone as a function of scenario. It is clear that all the scenarios have qualitatively similar speed profiles. Initially, the participants slow as the platoon of leading vehicles moves into the right lane, then the participants accelerated, reaching their peak speed at approximately half-way through the passing zone before decelerating.

In Figure 24, distance axes are in feet and extend from the beginning of 1-to-2 lane-addition transition through the end of the 2-to-1 lane-reduction transition. The 1-mile segment extends from 660 to 5940 feet. For each panel the blue traces represent individual participants. The red trace represents the ensemble average over distance. The red fills represents 95% confidence intervals on the ensemble averages. Box plots representing the distributions of speed across the 10 scenarios can be seen in Figure 25.

To examine whether the passing lane scenarios affected speed and accelerator position during the one-mile full two-lane segment of the passing zones, we calculated the arithmetic mean and standard deviation of accelerator position and vehicle speed for each participant and for each scenario. Similar to Experiment 1, we used Welch's test to control type I errors from violations of homogeneity of variance and to compare the equality of the means across the ten scenario conditions and the Games-Howell procedure for assessing pairwise comparisons.

None of these four analyses found any reliable effect of scenario. Though it would be logically unsound to conclude that no differences existed, we can conclude that any scenario differences in accelerator position or speed were insignificant in comparison to the overall variability in the data. We calculated coefficients of determination for a single-factor repeated-measures ANOVA on vehicle speed, and these metrics show that individual differences between participants account for 60% of the variability compared to the 2.4% accounted for by scenario type (see Figure 25). When the speeds are normalized relative to baseline, a more accurate visualization of the scenario differences can be obtained. Figure 26 shows that drivers were

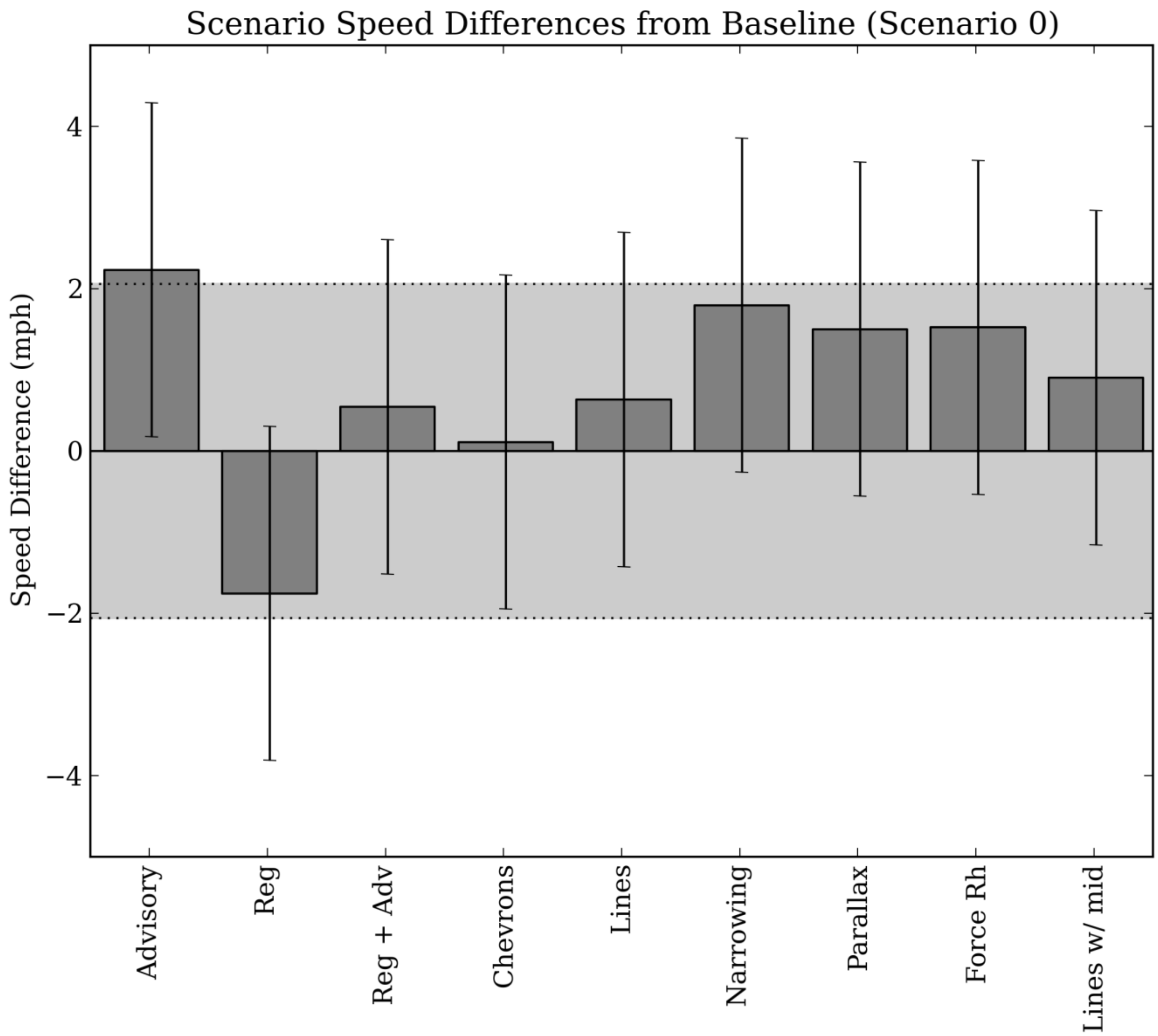


Figure 26 Speed differences normalized from baseline speed with error bars reflecting 95% confidence intervals after removing the between-subjects variability.

within ± 4.5 mph of their baseline speed across all of the scenarios. It appears that drivers demonstrated a great deal of individual variation in maximum speed (see Figure 27).

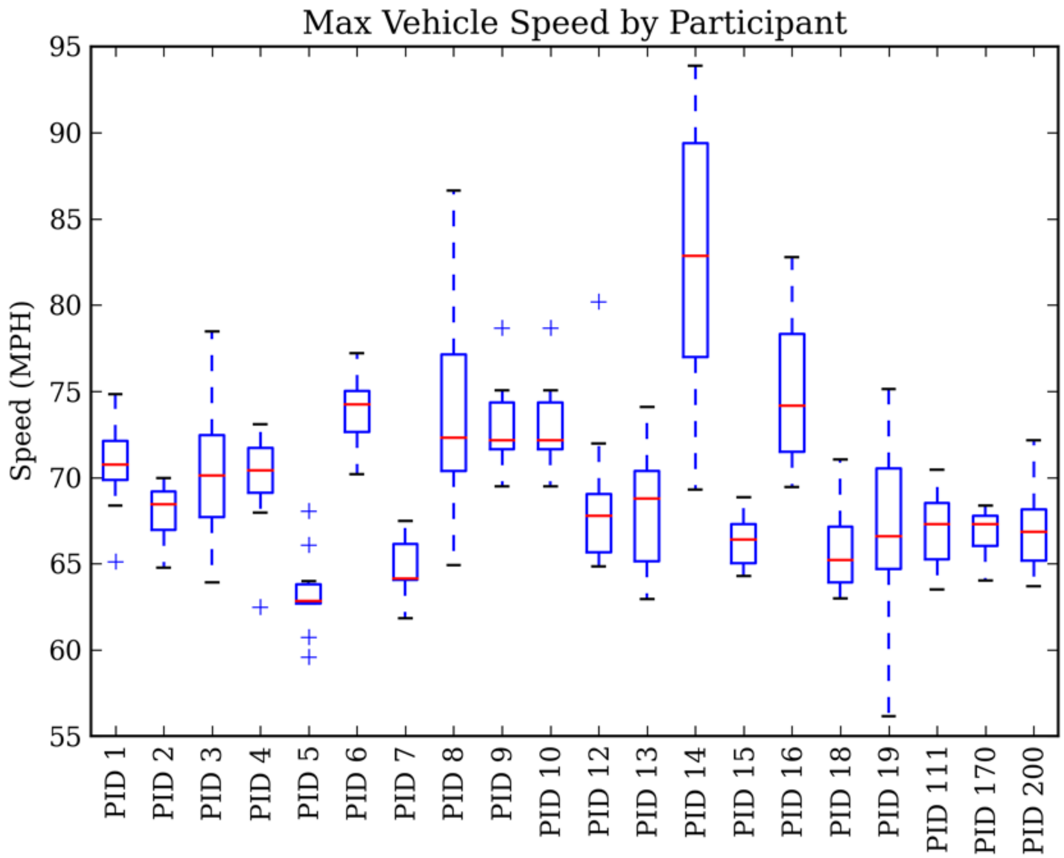
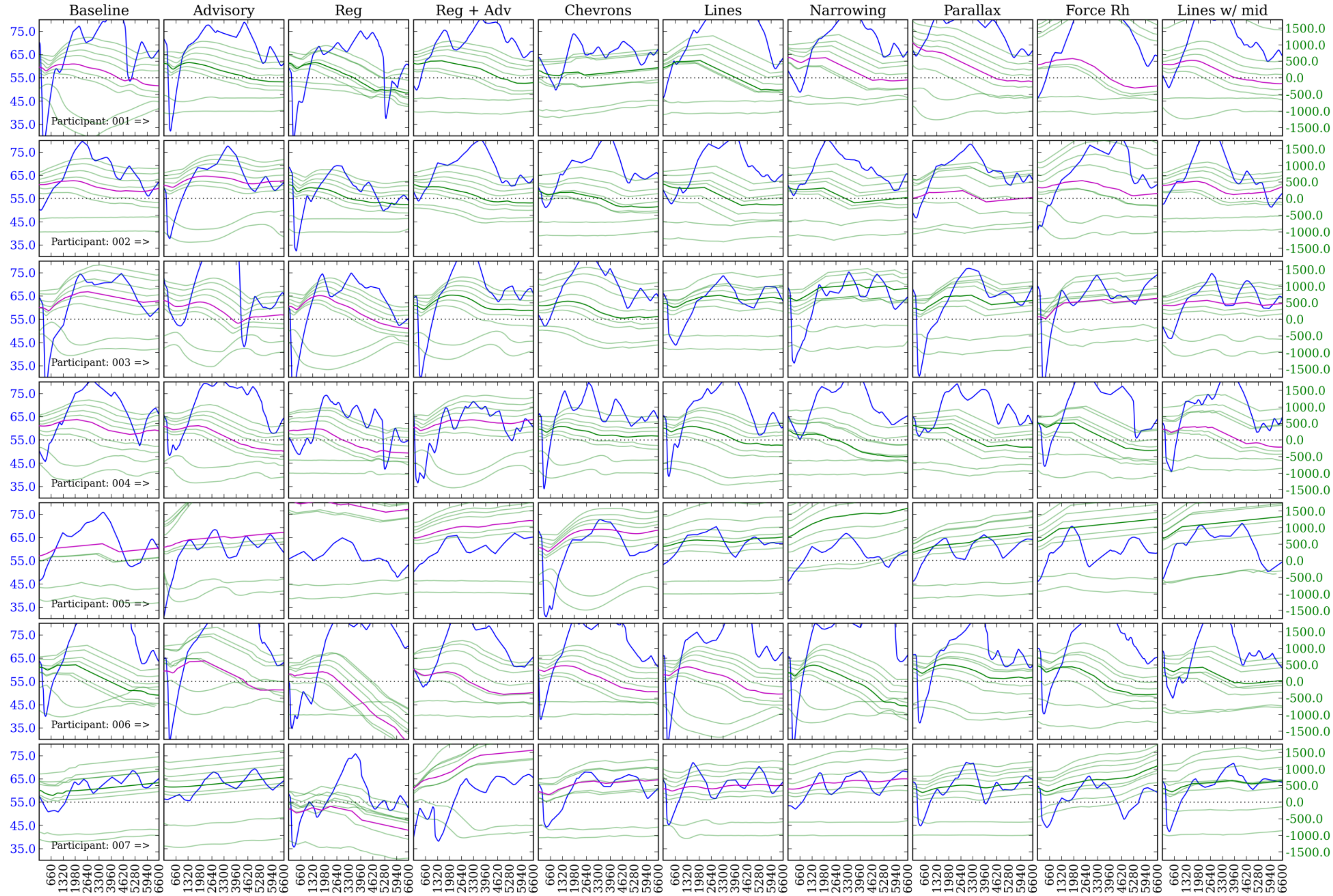
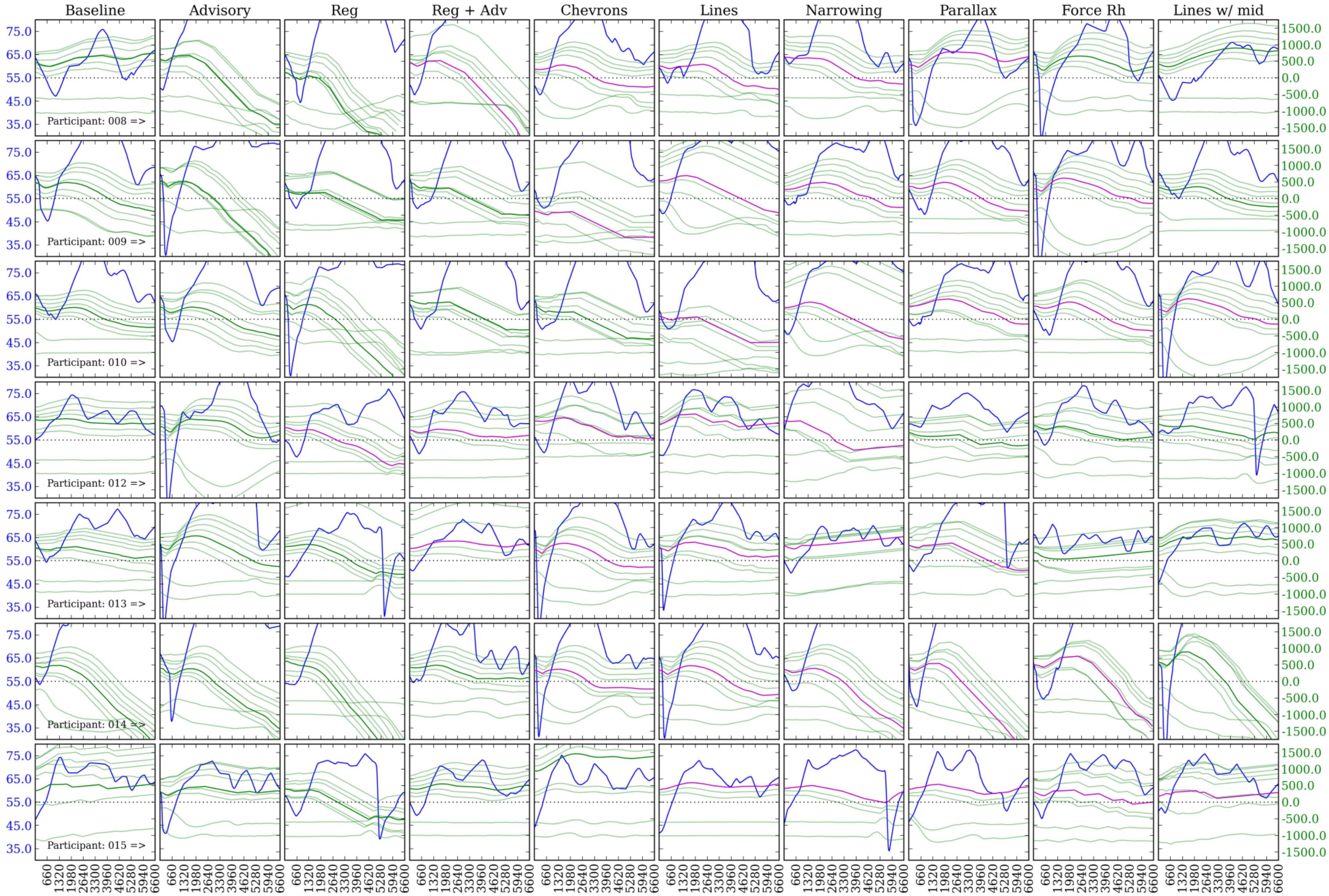


Figure 27 Speed differences normalized from baseline speed with error bars reflecting 95% confidence intervals after removing the between-subjects variability.


Baseline
Advisory
Reg
Reg + Adv
Chevrons
Lines
Narrowing
Parallax
Force Rh
Lines w/ mid
Participant: 001 =>
Participant: 002 =>
Participant: 003 =>
Participant: 004 =>
Participant: 005 =>
Participant: 006 =>
Participant: 007 =>
75.0
65.0
55.0
45.0
35.0
1500.0
1000.0
500.0
0.0
-500.0
-1000.0
-1500.0
660
1320
1980
2640
3300
3960
4620
5280
5940
6600



Baseline
Advisory
Reg
Reg + Adv
Chevrons
Lines
Narrowing
Parallax
Force Rh
Lines w/ mid
Participant: 008 =>
Participant: 009 =>
Participant: 010 =>
Participant: 012 =>
Participant: 013 =>
Participant: 014 =>
Participant: 015 =>
75.0
65.0
55.0
45.0
35.0
1500.0
1000.0
500.0
0.0
-500.0
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660
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3960
4620
5280
5940
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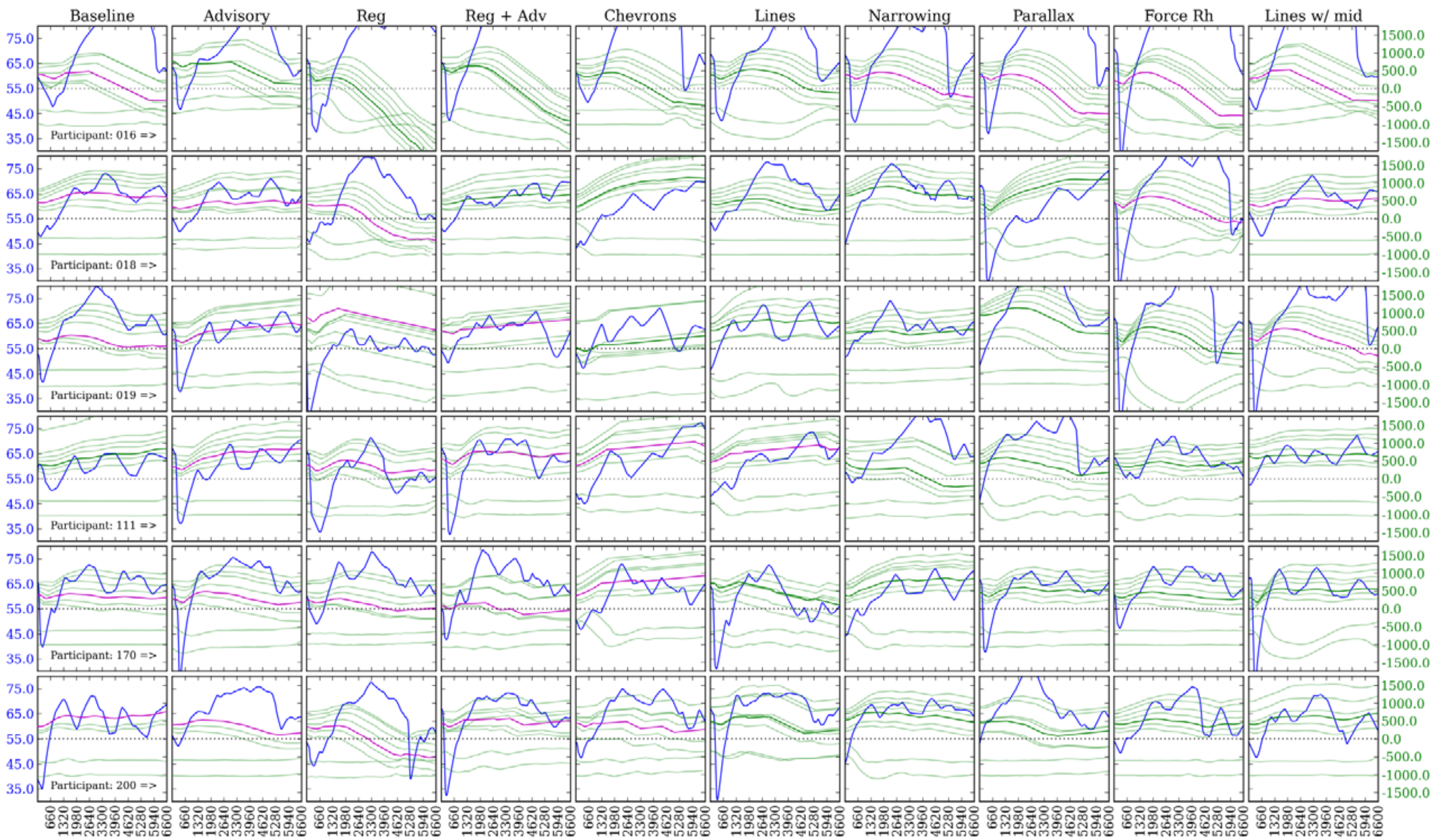


Figure 28 Each subplot represents a single passing lane event.

Participants are grouped as rows and the scenarios are grouped as columns. The blue trace represents the participant's speed over the 1.25 mile passing zone. The relative distances (in feet) of the other vehicles are depicted as the green traces. Negative relative distances indicate that the vehicle is behind the driver. Positive relative distances indicate the vehicle is in front of the driver. The bold green and violet lines indicate the type of the third vehicle in the platoon. Green -> sedan; Violet -> semi truck..

In each passing zone the driver was accompanied by a platoon of 7 to 9 vehicles heading the same direction. To examine passing efficiency, we calculated the mean number of vehicles passed for each scenario. Welch's test reveals a reliable effect of scenario on the number of vehicles passed [$W'(9, 77.345) = 2.060$, $p = .044$]. The effect was carried primarily by the regulatory scenario 2 and the regulatory + advisory scenario 3. The reduction in speed of the simulated vehicles in the right lane of these scenarios allowed participants to pass 2.5 more vehicles on average compared to the baseline (as well as significantly more compared to the scenarios 4, 5, 7, and 9). Figure 24 depicts ensemble vehicle speeds by distance. In these plots, the full two-lane passing zones begin at the 660 foot marks. At first it may seem counterintuitive, but participants often slow down before reaching the two-lane section of the passing zone. This information, however, can be reconciled when taken together with the relative headway plots in Figure 28. When drivers approach the passing zone, they decrease their headway to the car in front of them (*tailgating maneuver*). Once the passing lane is available, they transition to the left lane and leap frog over the vehicles they wish to pass.

Effects of size of the third vehicle to be passed. In each platoon, the size of the third vehicle ahead was systematically manipulated between scenarios. In half of the scenarios the vehicle was a normally sized sedan (small), and in the remaining half the vehicles were semi-truck tractor trailers (large). We hypothesized that drivers might have a stronger desire to pass the large vehicle, however, we found that the large vehicles were passed roughly the same number of times (38 of 100) as the small vehicle (42 of 1000). Based on the directionality of our hypothesis it is already evident that it is unsupported without any additional statistical analysis.

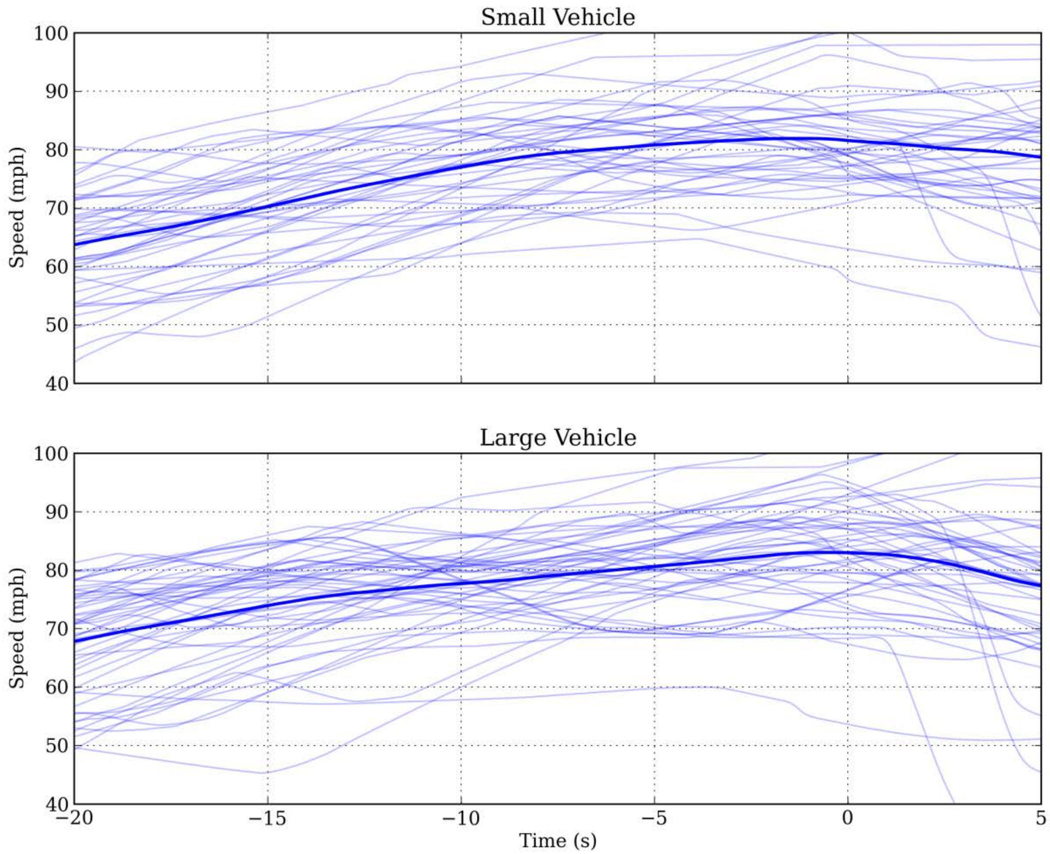


Figure 29 Ensemble plots depicting speeds passing the third vehicle. Participant overtakes the other vehicle at time 0.

It may be that even though a large vehicle increases the desire to pass, it is accompanied by an antagonistic stress mechanism that decreases the likelihood of passing. To examine the plausibility of this second hypothesis, the cases where participants passed the third vehicle were isolated and segregated by vehicle type. For each of these cases vehicle speed and accelerator position were examined for a 25 second window spanning the 20 seconds prior to overtaking the third vehicle to 5 seconds after overtaking the third vehicle.

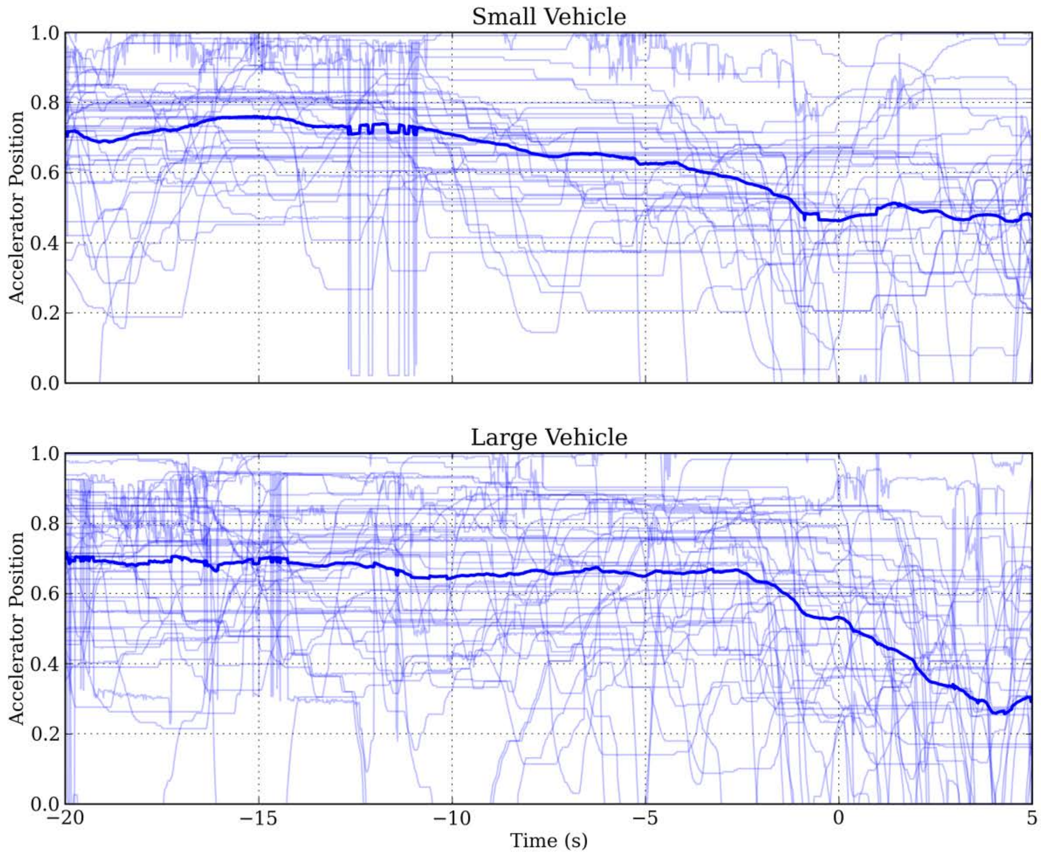
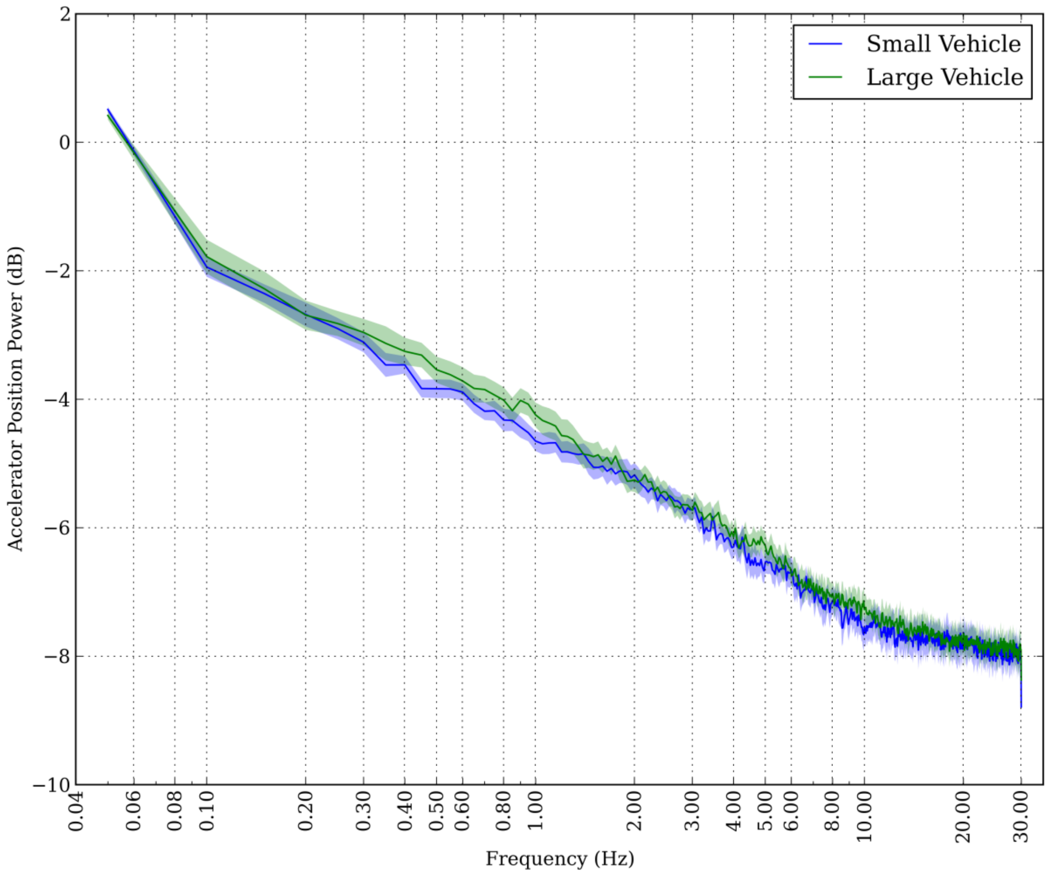


Figure 30 Ensemble plots depicting accelerator position while passing the third vehicle. Participant overtakes the other vehicle at time 0.

Figures 29 and 30 depict ensemble plots of vehicle speed and accelerator position respectively. With both types of vehicles, drivers sped up until they overtook the vehicle. Once the vehicle has been overtaken they gradually decelerate. Welch's method was used to obtain power spectral density estimates of accelerator position (see Figure 31). The power spectrum of accelerator position shows reliably more control input between 0.30 and 1.00 Hz (periods of 3.33 to 1.00 seconds, respectively) when passing large vehicles.

When the overtaking speeds are aggregated by participant and compared using a non-paired equal-variance one-sided *t*-test the speed result is not significant [$t(29) = 0.660$, p =



0[NT1].257, *d* = 0.237, obs. power = 0.151]. Vehicle speed RMS over the 20 seconds prior to overtaking the vehicle is also not significant [*t*(29) = 1.079, *p* = 0.145, *d* = 1.033, obs. power = 0.262]. However, because some participants did not pass both a single small or large vehicles during their drive, paired t-tests could not be performed on the data. When these participants are exluded, and a paired t-test is used on the remaining participants a marginally significant result on the overtaking vehicle speed is found [*t*(12) = 1.765, *p* = 0.051, *d* = 1.765, obs. power = 0.508]. On average, participants were about 3 mph faster when overtaking the larger vehicles (82.22 mph) as compared to the smaller vehicle (79.61 mph). The effect on RMS vehicle speed was also found reliable with the paired test [*t*(12) = 2.901, *p* = 0.007, *d* = 2.901, obs. power = 0.861]. This result suggests that the unreliable non-paired results maybe due to lack of statistical power and represent Type-II errors, although we cannot be certain because excluding 7 of 20 participants may compromise generalizability to the population at large

From Figure 30 the maximum difference in accelerator position appears to be about 2 seconds prior to overtaking the vehicle. Participants may let up on the pedal at this point to increase the controllability of the vehicle while manuvering in close quarters. An unpaired t-test on the participant means found that this difference was reliable [$t(29) = 1.719$, $p = 0.048$, $d = 0.616$, obs. power = 0.479]. Mean and RMS accelerator aggregated accelerator position data over the 20 seconds prior to overtaking the third vehicle were also subjected to t-tests and yielded non-significant results (even with paired observations). . Taken together, the effects of vehicle size suggest that participants who were observed to pass both small and large vehicles pass large vehicles with higher speed and more accelerator movement—effects consistent with our hypothesis that large vehicles induce a higher state of passing urgency

Summary & Conclusions of Experiment 2

The lane choice and deviation results indicate that our combination of instructions and slow leading traffic were successful in inducing drivers to reliably use the left lane of the passing zone and attempt to pass vehicles in the right lane. This result was critical for achieving the two aims of this experiment, which were to evaluate the effect of our speed interventions on left lane drivers and the effect of larger vehicles on passing behavior.

In contrast to Experiment 1, which found that a majority of our scenarios significantly reduced speed of right-lane drivers relative to baseline, Experiment 2 found no reliable evidence that any of the speed mitigations implemented in our nine scenarios affected the speed of drivers in the left hand lane. This non-effect is important since it suggests that our scenarios could slow down traffic in the right lane without similarly slowing traffic in the left lane, creating higher differential speeds between lanes and increasing passing efficiency.

Indeed, Experiment 2 found no effects of scenario on any of our driving performance measures, with one important exception: the Force-right/Neutral Zone Scenario resulted in reliable deviations into the right-hand lane at the beginning of the passing zone. This result suggests that drivers were generally sensitive to the change in center line markings.

The most interesting result of Experiment 2 pertains to the effects of vehicle size on accelerator position and speed. While the frequency of passing the third vehicle ahead in the platoon of slow moving vehicles was essentially the same for both the large and small vehicles, we found that passing large vehicles significantly increased the power spectrum of accelerator position between 0.30 and 1.00 Hz and also resulted in maximum speeds about 3 mph higher than when passing small vehicles. To our knowledge, this is the first objective data indicating that the size of the vehicle being passed has an effect on passing behavior consistent with an increased urgency to pass. These results clearly indicate that the relationship between vehicle size and urgency is an important topic for further research on passing safety.

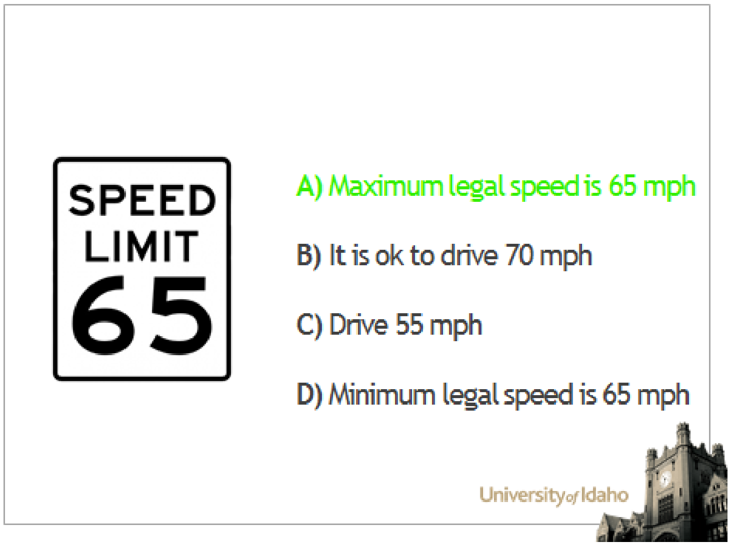
STUDY CONCLUSIONS AND RECOMMENDATIONS

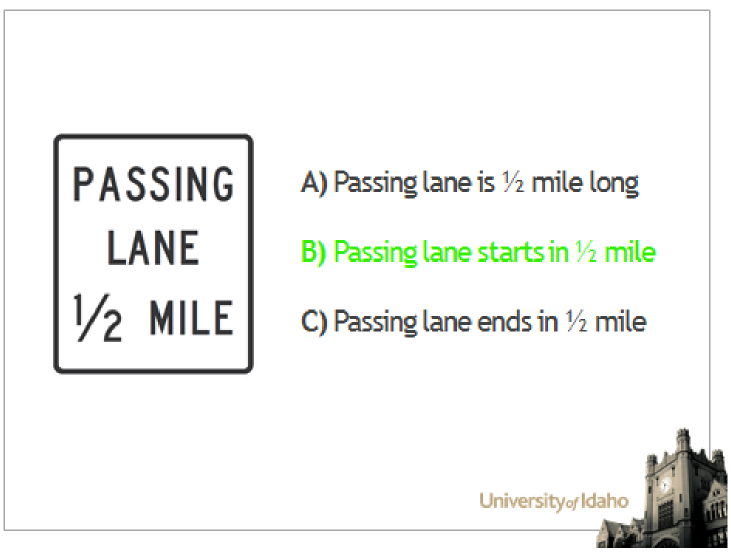
Taken together, the results of our two experiments clearly show that regulatory signs early in a passing zone that limit the speed of right-lane drivers relative to left-lane drivers offer the greatest opportunity for increasing the efficiency—and perhaps also the safety—of rural passing zones. We found that regulatory signs imposing split speed limits between the lanes (65 mph-left, 55 mph-right) or limiting RVs and trucks to 55 mph along with advisories to allow others to pass, reliably increased the difference in speed between left- and right-lane drivers, which should allow more passes to occur within each passing zone. This increase in passing efficiency has the potential to reduce driver frustration and passing urgency, and may therefore significantly enhance the safety of rural highways.

In contrast, the passive speed reduction scenarios we tested (Chevrons, transverse lines, parallax, lane narrowing) were all far less effective in reducing speed of drivers in the right-hand lane. This result was surprising given that previous research on passive speed mitigations found significant reductions in speeds approaching roundabouts and freeway off-ramps. The difference in results could be due to any number of factors, but two hypotheses seem particularly important to test: a) right-lane drivers in our study may have been distracted by the need to monitor vehicles passing them and finding a gap to merge and may not have paid attention to the passive highway markings, and b) passive speed measures may only affect speed control in situations where a driver is already slowing down, rather than maintaining constant speed. Future research will be needed to determine why passive speed reduction appears to work for some highway applications but not for passing zones.

Finally, our results indicate that passing urgency may indeed be higher when passing large sized vehicles such as tractor-trailer trucks. This increased urgency could lead drivers to engage in riskier passing decisions. This conclusion requires further research to validate the effect and explore its complexities.

APPENDIX A: POWERPOINT SIGN QUIZ GIVEN TO PARTICIPANTS BEFORE THE EXPERIMENT.





A) Constantly drive in the left lane, regardless of speed

B) No passing allowed

C) Whenever possible, stay in the right lane unless passing a slower vehicle

A) Slow vehicles drive in the right lane

B) Drive in the left lane, regardless of speed

C) Vehicles that are pulling trailers must keep right and allow other vehicles to pass

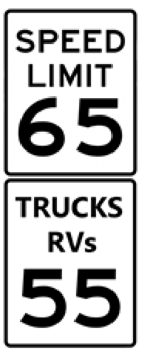
D) Both A & C

A) Always drive in the left lane, just to go faster.

B) Same speed limit in both lanes

C) Different speed limit depending on which lane you are in. 65 - left lane; 55 - right lane

University of Idaho



A) Large vehicles, such as trucks and RVs must drive 55, while all other traffic is allowed to drive 65.

B) Trucks/RVs drive 55 mph if not in a hurry.

C) Trucks/RVs only drive 55 mph if there is traffic behind you

D) Trucks must maintain a minimum speed of 55 mph

University of Idaho

A) Minimum legal speed is 65 mph

B) Drive 72 mph

C) Speed limit for all vehicles is 65 mph, overriding previous signage

D) All vehicles must drive exactly 65 mph

University of Idaho

A) Lane narrowing

B) Right lane ends

C) Left lane ends

University of Idaho

A) Right lane is ending

B) Lane narrowing

C) Left lane is ending

University of Idaho

APPENDIX B: RV TOWING INSTRUCTIONS USED FOR EXPERIMENT 1

RV Towing
Instructions

This experiment examines how people drive on rural highways.

Your task will be to steer a simulated vehicle pulling a recreational vehicle (a trailer) over a road through a simulation of the Alaskan countryside. Your goal is to keep your vehicle centered in your lane and moving at an appropriate speed, just as you would in everyday driving. Just like with any car, to turn right you move the top of the steering wheel to the right. To turn left you move the top of the steering wheel to the left. To accelerate you press the gas pedal. To slow down, you press the brake pedal. Turn signals operate just like in a real vehicle.

In this experiment you will go through 1 trial lasting approximately 50 minutes which will simulate a 50 mile drive in traffic returning from a weekend in the Alaskan wilderness.   There will be vehicles ahead and behind you as well as in the oncoming lane. You should pay careful attention to other vehicles, road signs, speed limits, etc. and use normal driving etiquette (obeying speed limits, using turn signals, using passing lanes to pass slow moving vehicles, letting faster vehicles behind you pass, etc.) just as you would if you were driving on a real rural highway pulling a recreational vehicle in traffic.

From time to time, the other vehicles in the simulation will slow and pull off on the shoulder. When this occurs, you should maintain a safe distance, stay in your lane, and accelerate back up to your cruising speed once the lane is clear.

Do you have any questions?

Now please explain to me, in your own words, what you will be doing in this study.

After approximately 25 miles, a message will appear on the screen asking you to pull over in front of a row of orange barrels and take a break. At this time, we want you to park the car on the shoulder, placing the transmission in “Park” and exit the vehicle so that you can get up, walk around, and stretch your legs for a minute.

To begin each trial you will need to depress the brake pedal to release the transmission lock and shift the gear shift into “D” or “drive.”

Do you have any questions?

APPENDIX C: NON-TOWING INSTRUCTIONS USED FOR EXPERIMENT 2

Non-Towing
Instructions

This experiment examines how people drive on rural highways.

Your task will be to steer a simulated vehicle over a road through a simulation of the Alaskan countryside. Your goal is to keep your vehicle centered in your lane and moving at an appropriate speed, just as you would in everyday driving. Just like with any car, to turn right you move the top of the steering wheel to the right. To turn left you move the top of the steering wheel to the left. To accelerate you press the gas pedal. To slow down, you press the brake pedal. Turn signals operate just like in a real vehicle.

In this experiment you will go through 1 trial lasting approximately 50 minutes which will simulate a 50 mile drive in traffic returning from a weekend in the Alaskan wilderness. There will be vehicles ahead and behind you as well as in the oncoming lane. You should pay careful attention to other vehicles, road signs, speed limits, etc. and use normal driving etiquette (obeying speed limits, using turn signals, using passing lanes to pass slow moving vehicles, letting faster vehicles behind you pass, etc.) just as you would if you were driving on a real rural highway in traffic, and in a hurry to get home. Also during this drive, you are only allowed to pass a car if there is another open lane to pass in (Passing Lane). You cannot pass someone by going into the oncoming lane (2 lane highway), even if the road markings allow you to pass (ex. dotted line), because this can cause our simulation to crash.

From time to time, the other vehicles in the simulation will slow and pull off on the shoulder. When this occurs, you should maintain a safe distance, stay in your lane, and accelerate back up to your cruising speed once the lane is clear.

Do you have any questions?

Now please explain to me, in your own words, what you will be doing in this study.

After approximately 25 miles, a message will appear on the screen asking you to pull over in front of a row of orange barrels and take a break. At this time, we want you to park the car on the shoulder, placing the transmission in “Park” and exit the vehicle so that you can get up, walk around, and stretch your legs for a minute.

To begin each trial you will need to depress the brake pedal to release the transmission lock and shift the gear shift into “D” or “drive.”

Do you have any questions?

APPENDIX D: ANOVA TABLES FOR EXPERIMENT 1

TESTS OF WITHIN SUBJECTS EFFECTS for Mean Accelerator Pedal Position

Source		Type III SS	eps	df	MS	F	Sig.	et2_G	Obs.	SE	95% CI	lambda	Obs. Power
section	Sphericity Assumed	0.040	-	2	0.020	1.865	0.164	0.007	300	0.006	0.012	19.290	0.976
	Greenhouse-Geisser	0.040	0.840	1.680	0.024	1.865	0.171	0.007	300	0.006	0.012	19.290	0.957
Error(section)	Sphericity Assumed	0.626	-	58	0.011								
	Greenhouse-Geisser	0.626	0.840	48.733	0.013								
scenario	Sphericity Assumed	0.093	-	9	0.010	1.993	0.040	0.017	90	0.008	0.015	6.186	0.338
	Greenhouse-Geisser	0.093	0.689	6.202	0.015	1.993	0.067	0.017	90	0.008	0.015	6.186	0.273
Error(scenario)	Sphericity Assumed	1.351	-	261	0.005								
	Greenhouse-Geisser	1.351	0.689	179.854	0.008								
section * scenario	Sphericity Assumed	0.246	-	18	0.014	2.106	0.005	0.044	30	0.015	0.029	2.179	0.103
	Greenhouse-Geisser	0.246	0.468	8.430	0.029	2.106	0.033	0.044	30	0.015	0.029	2.179	0.085
Error(section * scenario)	Sphericity Assumed	3.385	-	522	0.006								
	Greenhouse-Geisser	3.385	0.468	244.467	0.014								

Estimated Marginal Means for section

section	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	0.429	0.004	0.421	0.438
2	0.416	0.002	0.411	0.420
3	0.430	0.006	0.418	0.443

Estimated Marginal Means for scenario

scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
0	0.443	0.008	0.428	0.459
1	0.430	0.007	0.415	0.444
2	0.404	0.010	0.385	0.423
3	0.423	0.008	0.408	0.439
4	0.426	0.010	0.406	0.445
5	0.420	0.010	0.401	0.438
6	0.435	0.008	0.420	0.450
7	0.416	0.008	0.402	0.431
8	0.428	0.008	0.412	0.443
9	0.427	0.010	0.408	0.446

Estimated Marginal Means for section * scenario

section	scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	0	0.451	0.016	0.420	0.482
1	1	0.425	0.011	0.403	0.447
1	2	0.359	0.022	0.316	0.402
1	3	0.424	0.011	0.403	0.445
1	4	0.435	0.015	0.406	0.463
1	5	0.422	0.013	0.395	0.448
1	6	0.438	0.012	0.416	0.461
1	7	0.444	0.010	0.425	0.463
1	8	0.449	0.012	0.426	0.473
1	9	0.448	0.010	0.428	0.468
2	0	0.433	0.009	0.416	0.450
2	1	0.414	0.007	0.401	0.428
2	2	0.406	0.004	0.398	0.415
2	3	0.398	0.007	0.384	0.412
2	4	0.419	0.006	0.408	0.430
2	5	0.420	0.008	0.405	0.435
2	6	0.414	0.007	0.400	0.428
2	7	0.413	0.008	0.398	0.428
2	8	0.418	0.007	0.405	0.432
2	9	0.422	0.009	0.404	0.439
3	0	0.447	0.015	0.417	0.477
3	1	0.449	0.018	0.415	0.484
3	2	0.446	0.016	0.414	0.477
3	3	0.447	0.019	0.410	0.485
3	4	0.424	0.025	0.374	0.474
3	5	0.418	0.024	0.370	0.466
3	6	0.453	0.019	0.416	0.490
3	7	0.392	0.018	0.357	0.427
3	8	0.416	0.019	0.379	0.454
3	9	0.410	0.026	0.360	0.461

TESTS OF WITHIN SUBJECTS EFFECTS for Standard Deviation of Accelerator Pedal Position

Source		Type III SS	eps	df	MS	F	Sig.	et2_G	Obs.	SE	95% CI	lambda	Obs. Power
section	Sphericity Assumed	1.513	-	2	0.756	104.145	6.369e-20	0.338	300	0.005	0.010	1077.366	1
	Greenhouse-Geisser	1.513	0.654	1.307	1.157	104.145	8.017e-14	0.338	300	0.005	0.010	1077.366	1
Error(section)	Sphericity Assumed	0.421	-	58	0.007								
	Greenhouse-Geisser	0.421	0.654	37.909	0.011								
scenario	Sphericity Assumed	0.017	-	9	0.002	0.454	0.904	0.004	90	0.007	0.013	1.408	0.098
	Greenhouse-Geisser	0.017	0.782	7.042	0.002	0.454	0.868	0.004	90	0.007	0.013	1.408	0.092
Error(scenario)	Sphericity Assumed	1.104	-	261	0.004								
	Greenhouse-Geisser	1.104	0.782	204.226	0.005								
section * scenario	Sphericity Assumed	0.073	-	18	0.004	1.124	0.324	0.016	30	0.011	0.022	1.163	0.076
	Greenhouse-Geisser	0.073	0.527	9.478	0.008	1.124	0.345	0.016	30	0.011	0.022	1.163	0.069
Error(section * scenario)	Sphericity Assumed	1.879	-	522	0.004								
	Greenhouse-Geisser	1.879	0.527	274.853	0.007								

Estimated Marginal Means for section

section	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	0.047	0.003	0.040	0.054
2	0.142	0.003	0.136	0.149
3	0.121	0.005	0.111	0.132

Estimated Marginal Means for scenario

scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
0	0.099	0.008	0.083	0.115
1	0.108	0.009	0.091	0.125
2	0.111	0.008	0.095	0.128
3	0.101	0.009	0.085	0.118
4	0.106	0.009	0.088	0.123
5	0.104	0.009	0.086	0.122
6	0.095	0.009	0.078	0.112
7	0.106	0.008	0.090	0.122
8	0.103	0.009	0.085	0.121
9	0.103	0.008	0.087	0.119

Estimated Marginal Means for section * scenario

section	scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	0	0.046	0.011	0.024	0.069
1	1	0.056	0.012	0.032	0.079
1	2	0.075	0.013	0.050	0.099
1	3	0.049	0.009	0.031	0.067
1	4	0.036	0.009	0.017	0.054
1	5	0.049	0.011	0.027	0.070
1	6	0.050	0.014	0.023	0.077
1	7	0.039	0.009	0.022	0.056
1	8	0.034	0.007	0.019	0.048
1	9	0.036	0.011	0.015	0.058
2	0	0.130	0.011	0.109	0.151
2	1	0.146	0.011	0.126	0.167
2	2	0.144	0.011	0.123	0.165
2	3	0.144	0.010	0.124	0.164
2	4	0.146	0.010	0.127	0.165
2	5	0.142	0.009	0.125	0.160
2	6	0.138	0.012	0.114	0.161
2	7	0.146	0.010	0.126	0.165
2	8	0.138	0.008	0.122	0.155
2	9	0.150	0.011	0.128	0.172
3	0	0.120	0.016	0.089	0.151
3	1	0.122	0.017	0.088	0.155
3	2	0.115	0.018	0.081	0.150
3	3	0.111	0.018	0.076	0.146
3	4	0.135	0.017	0.101	0.169
3	5	0.121	0.020	0.081	0.161
3	6	0.097	0.015	0.066	0.127
3	7	0.133	0.014	0.105	0.162
3	8	0.137	0.021	0.096	0.178
3	9	0.122	0.013	0.097	0.147

TESTS OF WITHIN SUBJECTS EFFECTS for Mean Steering Wheel Angle

Source		Type III SS	eps	df	MS	F	Sig.	et2_G	Obs.	SE	95% CI	lambda	Obs. Power
section	Sphericity Assumed	1.502	-	2	0.751	5.143	0.009	0.013	300	0.023	0.044	53.206	1.000
	Greenhouse-Geisser	1.502	0.945	1.891	0.794	5.143	0.010	0.013	300	0.023	0.044	53.206	1.000
Error(section)	Sphericity Assumed	8.467	-	58	0.146								
	Greenhouse-Geisser	8.467	0.945	54.828	0.154								
scenario	Sphericity Assumed	2.318	-	9	0.258	1.782	0.072	0.020	90	0.040	0.079	5.530	0.301
	Greenhouse-Geisser	2.318	0.818	7.363	0.315	1.782	0.088	0.020	90	0.040	0.079	5.530	0.269
Error(scenario)	Sphericity Assumed	37.723	-	261	0.145								
	Greenhouse-Geisser	37.723	0.818	213.532	0.177								
section * scenario	Sphericity Assumed	1.561	-	18	0.087	0.736	0.775	0.014	30	0.063	0.123	0.761	0.066
	Greenhouse-Geisser	1.561	0.533	9.601	0.163	0.736	0.685	0.014	30	0.063	0.123	0.761	0.062
Error(section * scenario)	Sphericity Assumed	61.534	-	522	0.118								
	Greenhouse-Geisser	61.534	0.533	278.418	0.221								

Estimated Marginal Means for section

section	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	0.047	0.003	0.040	0.054
2	0.142	0.003	0.136	0.149
3	0.121	0.005	0.111	0.132

Estimated Marginal Means for scenario

scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
0	0.099	0.008	0.083	0.115
1	0.108	0.009	0.091	0.125
2	0.111	0.008	0.095	0.128
3	0.101	0.009	0.085	0.118
4	0.106	0.009	0.088	0.123
5	0.104	0.009	0.086	0.122
6	0.095	0.009	0.078	0.112
7	0.106	0.008	0.090	0.122
8	0.103	0.009	0.085	0.121
9	0.103	0.008	0.087	0.119

Estimated Marginal Means for section * scenario

section	scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	0	0.046	0.011	0.024	0.069
1	1	0.056	0.012	0.032	0.079
1	2	0.075	0.013	0.050	0.099
1	3	0.049	0.009	0.031	0.067
1	4	0.036	0.009	0.017	0.054
1	5	0.049	0.011	0.027	0.070
1	6	0.050	0.014	0.023	0.077
1	7	0.039	0.009	0.022	0.056
1	8	0.034	0.007	0.019	0.048
1	9	0.036	0.011	0.015	0.058
2	0	0.130	0.011	0.109	0.151
2	1	0.146	0.011	0.126	0.167
2	2	0.144	0.011	0.123	0.165
2	3	0.144	0.010	0.124	0.164
2	4	0.146	0.010	0.127	0.165
2	5	0.142	0.009	0.125	0.160
2	6	0.138	0.012	0.114	0.161
2	7	0.146	0.010	0.126	0.165
2	8	0.138	0.008	0.122	0.155
2	9	0.150	0.011	0.128	0.172
3	0	0.120	0.016	0.089	0.151
3	1	0.122	0.017	0.088	0.155
3	2	0.115	0.018	0.081	0.150
3	3	0.111	0.018	0.076	0.146
3	4	0.135	0.017	0.101	0.169
3	5	0.121	0.020	0.081	0.161
3	6	0.097	0.015	0.066	0.127
3	7	0.133	0.014	0.105	0.162
3	8	0.137	0.021	0.096	0.178
3	9	0.122	0.013	0.097	0.147

TESTS OF WITHIN SUBJECTS EFFECTS for Standard Deviation of Steering Wheel Angle

Source		Type III SS	eps	df	MS	F	Sig.	et2_G	Obs.	SE	95% CI	lambda	Obs. Power
section	Sphericity Assumed	4.898	-	2	2.449	4.587	0.014	0.009	300	0.043	0.084	47.455	1.000
	Greenhouse-Geisser	4.898	0.997	1.993	2.458	4.587	0.014	0.009	300	0.043	0.084	47.455	1.000
Error(section)	Sphericity Assumed	30.964	-	58	0.534								
	Greenhouse-Geisser	30.964	0.997	57.800	0.536								
scenario	Sphericity Assumed	20.132	-	9	2.237	4.356	2.622e-05	0.039	90	0.076	0.149	13.519	0.708
	Greenhouse-Geisser	20.132	0.546	4.911	4.099	4.356	0.001	0.039	90	0.076	0.149	13.519	0.510
Error(scenario)	Sphericity Assumed	134.020	-	261	0.513								
	Greenhouse-Geisser	134.020	0.546	142.423	0.941								
section * scenario	Sphericity Assumed	24.119	-	18	1.340	3.240	8.524e-06	0.046	30	0.118	0.231	3.352	0.139
	Greenhouse-Geisser	24.119	0.355	6.387	3.776	3.240	0.004	0.046	30	0.118	0.231	3.352	0.099
Error(section * scenario)	Sphericity Assumed	215.880	-	522	0.414								
	Greenhouse-Geisser	215.880	0.355	185.211	1.166								

Estimated Marginal Means for section

section	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	0.882	0.044	0.795	0.968
2	4.972	0.129	4.718	5.225
3	2.277	0.110	2.061	2.492

Estimated Marginal Means for scenario

scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
0	2.540	0.254	2.042	3.038
1	2.622	0.242	2.147	3.097
2	2.684	0.212	2.268	3.100
3	2.687	0.263	2.171	3.202
4	2.923	0.275	2.384	3.462
5	2.928	0.271	2.396	3.460
6	2.558	0.251	2.067	3.049
7	2.485	0.235	2.024	2.946
8	2.774	0.258	2.269	3.279
9	2.898	0.307	2.296	3.500

Estimated Marginal Means for section * scenario

section	scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	0	0.910	0.146	0.624	1.195
1	1	0.774	0.113	0.553	0.995
1	2	1.361	0.206	0.958	1.764
1	3	0.843	0.117	0.614	1.072
1	4	0.932	0.137	0.664	1.200
1	5	1.003	0.159	0.691	1.316
1	6	0.739	0.133	0.478	1.000
1	7	0.693	0.106	0.484	0.901
1	8	1.005	0.132	0.747	1.263
1	9	0.556	0.077	0.405	0.707
2	0	4.695	0.447	3.819	5.571
2	1	4.908	0.367	4.189	5.627
2	2	4.783	0.302	4.192	5.374
2	3	4.635	0.324	4.000	5.269
2	4	5.487	0.481	4.545	6.429
2	5	5.484	0.444	4.613	6.355
2	6	4.675	0.372	3.946	5.405
2	7	4.789	0.389	4.027	5.551
2	8	5.062	0.380	4.318	5.806
2	9	5.198	0.547	4.126	6.270
3	0	2.015	0.335	1.358	2.671
3	1	2.185	0.298	1.600	2.769
3	2	1.909	0.222	1.474	2.344
3	3	2.582	0.520	1.564	3.601
3	4	2.350	0.266	1.828	2.872
3	5	2.298	0.298	1.713	2.882
3	6	2.260	0.387	1.501	3.019
3	7	1.974	0.209	1.564	2.384
3	8	2.254	0.390	1.489	3.020
3	9	2.940	0.437	2.083	3.798

TESTS OF WITHIN SUBJECTS EFFECTS for Mean Vehicle Speed

Source		Type III SS	eps	df	MS	F	Sig.	et2_G	Obs.	SE	95% CI	lambda	Obs. Power
section	Sphericity Assumed	11165.372	-	2	5582.686	102.679	8.781e-20	0.321	300	0.435	0.852	1062.196	1
	Greenhouse-Geisser	11165.372	0.550	1.099	10155.799	102.679	6.554e-12	0.321	300	0.435	0.852	1062.196	1
Error(section)	Sphericity Assumed	3153.478	-	58	54.370								
	Greenhouse-Geisser	3153.478	0.550	31.883	98.908								
scenario	Sphericity Assumed	1331.223	-	9	147.914	4.880	4.734e-06	0.038	90	0.583	1.143	15.146	0.768
	Greenhouse-Geisser	1331.223	0.506	4.555	292.282	4.880	6.087e-04	0.038	90	0.583	1.143	15.146	0.542
Error(scenario)	Sphericity Assumed	7910.316	-	261	30.308								
	Greenhouse-Geisser	7910.316	0.506	132.083	59.889								
section * scenario	Sphericity Assumed	564.546	-	18	31.364	1.991	0.009	0.016	30	0.726	1.424	2.060	0.099
	Greenhouse-Geisser	564.546	0.481	8.667	65.138	1.991	0.043	0.016	30	0.726	1.424	2.060	0.083
Error(section * scenario)	Sphericity Assumed	8223.438	-	522	15.754								
	Greenhouse-Geisser	8223.438	0.481	251.341	32.718								

Estimated Marginal Means for section

section	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	63.890	0.326	63.251	64.528
2	57.703	0.348	57.022	58.384
3	55.588	0.426	54.753	56.424

Estimated Marginal Means for scenario

scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
0	60.562	0.805	58.984	62.141
1	59.400	0.713	58.002	60.797
2	56.581	0.670	55.267	57.895
3	57.098	0.712	55.702	58.493
4	59.284	0.686	57.941	60.628
5	59.717	0.743	58.260	61.174
6	59.574	0.754	58.096	61.052
7	59.813	0.750	58.343	61.283
8	58.578	0.923	56.768	60.388
9	59.996	0.829	58.371	61.622

Estimated Marginal Means for section * scenario

section	scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	0	64.361	0.894	62.609	66.112
1	1	64.155	1.092	62.014	66.296
1	2	62.208	1.096	60.060	64.355
1	3	63.188	1.050	61.131	65.245
1	4	63.629	0.841	61.980	65.278
1	5	64.501	0.999	62.542	66.460
1	6	64.214	1.004	62.246	66.182
1	7	64.349	1.106	62.181	66.516
1	8	63.604	1.096	61.455	65.752
1	9	64.688	1.158	62.417	66.959
2	0	59.884	1.296	57.343	62.425
2	1	57.770	0.965	55.877	59.662
2	2	53.371	0.741	51.918	54.824
2	3	54.200	0.802	52.629	55.771
2	4	58.282	1.040	56.242	60.321
2	5	58.042	1.128	55.832	60.252
2	6	58.889	1.009	56.911	60.867
2	7	58.396	1.071	56.297	60.494
2	8	58.663	1.199	56.314	61.012
2	9	59.534	1.114	57.351	61.717
3	0	57.442	1.626	54.255	60.629
3	1	56.275	1.161	53.999	58.551
3	2	54.164	0.860	52.479	55.849
3	3	53.905	1.002	51.942	55.868
3	4	55.943	1.211	53.569	58.317
3	5	56.607	1.263	54.131	59.084
3	6	55.619	1.382	52.909	58.328
3	7	56.696	1.302	54.144	59.247
3	8	53.467	1.854	49.833	57.102
3	9	55.766	1.538	52.751	58.782

TESTS OF WITHIN SUBJECTS EFFECTS for Standard Deviation of Vehicle Speed

Source		Type III SS	eps	df	MS	F	Sig.	et2_G	Obs.	SE	95% CI	lambda	Obs. Power
section	Sphericity Assumed	2593.643	-	2	1296.822	288.673	7.114e-31	0.963	300	0.125	0.245	2986.275	1
	Greenhouse-Geisser	2593.643	0.525	1.050	2469.490	288.673	2.476e-17	0.963	300	0.125	0.245	2986.275	1
Error(section)	Sphericity Assumed	260.556	-	58	4.492								
	Greenhouse-Geisser	260.556	0.525	30.458	8.555								
scenario	Sphericity Assumed	21.957	-	9	2.440	0.760	0.654	0.008	90	0.190	0.372	2.359	0.138
	Greenhouse-Geisser	21.957	0.712	6.409	3.426	0.760	0.610	0.008	90	0.190	0.372	2.359	0.122
Error(scenario)	Sphericity Assumed	837.824	-	261	3.210								
	Greenhouse-Geisser	837.824	0.712	185.861	4.508								
section * scenario	Sphericity Assumed	44.669	-	18	2.482	1.079	0.370	0.017	30	0.277	0.544	1.116	0.075
	Greenhouse-Geisser	44.669	0.492	8.863	5.040	1.079	0.378	0.017	30	0.277	0.544	1.116	0.067
Error(section * scenario)	Sphericity Assumed	1200.311	-	522	2.299								
	Greenhouse-Geisser	1200.311	0.492	257.018	4.670								

Estimated Marginal Means for section

section	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	0.882	0.044	0.795	0.968
2	4.972	0.129	4.718	5.225
3	2.277	0.110	2.061	2.492

Estimated Marginal Means for scenario

scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
0	2.540	0.254	2.042	3.038
1	2.622	0.242	2.147	3.097
2	2.684	0.212	2.268	3.100
3	2.687	0.263	2.171	3.202
4	2.923	0.275	2.384	3.462
5	2.928	0.271	2.396	3.460
6	2.558	0.251	2.067	3.049
7	2.485	0.235	2.024	2.946
8	2.774	0.258	2.269	3.279
9	2.898	0.307	2.296	3.500

Estimated Marginal Means for section * scenario

section	scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	0	0.910	0.146	0.624	1.195
1	1	0.774	0.113	0.553	0.995
1	2	1.361	0.206	0.958	1.764
1	3	0.843	0.117	0.614	1.072
1	4	0.932	0.137	0.664	1.200
1	5	1.003	0.159	0.691	1.316
1	6	0.739	0.133	0.478	1.000
1	7	0.693	0.106	0.484	0.901
1	8	1.005	0.132	0.747	1.263
1	9	0.556	0.077	0.405	0.707
2	0	4.695	0.447	3.819	5.571
2	1	4.908	0.367	4.189	5.627
2	2	4.783	0.302	4.192	5.374
2	3	4.635	0.324	4.000	5.269
2	4	5.487	0.481	4.545	6.429
2	5	5.484	0.444	4.613	6.355
2	6	4.675	0.372	3.946	5.405
2	7	4.789	0.389	4.027	5.551
2	8	5.062	0.380	4.318	5.806
2	9	5.198	0.547	4.126	6.270
3	0	2.015	0.335	1.358	2.671
3	1	2.185	0.298	1.600	2.769
3	2	1.909	0.222	1.474	2.344
3	3	2.582	0.520	1.564	3.601
3	4	2.350	0.266	1.828	2.872
3	5	2.298	0.298	1.713	2.882
3	6	2.260	0.387	1.501	3.019
3	7	1.974	0.209	1.564	2.384
3	8	2.254	0.390	1.489	3.020
3	9	2.940	0.437	2.083	3.798

APPENDIX E: ANOVA TABLES FOR EXPERIMENT 2

TESTS OF WITHIN SUBJECTS EFFECTS for Mean Accelerator Pedal Position

Source		Type III SS	eps	df	MS	F	Sig.	et2_G	Obs.	SE	95% CI	lambda	Obs. Power
section	Sphericity Assumed	0.837	-	2	0.419	13.242	4.329e-05	0.117	200	0.013	0.025	139.386	1
	Greenhouse-Geisser	0.837	0.693	1.386	0.604	13.242	4.153e-04	0.117	200	0.013	0.025	139.386	1
Error(section)	Sphericity Assumed	1.201	-	38	0.032								
	Greenhouse-Geisser	1.201	0.693	26.332	0.046								
scenario	Sphericity Assumed	0.146	-	9	0.016	1.556	0.132	0.020	60	0.013	0.026	4.913	0.263
	Greenhouse-Geisser	0.146	0.571	5.141	0.028	1.556	0.178	0.020	60	0.013	0.026	4.913	0.197
Error(scenario)	Sphericity Assumed	1.781	-	171	0.010								
	Greenhouse-Geisser	1.781	0.571	97.671	0.018								
section * scenario	Sphericity Assumed	0.227	-	18	0.013	1.154	0.298	0.032	20	0.023	0.046	1.215	0.077
	Greenhouse-Geisser	0.227	0.461	8.302	0.027	1.154	0.330	0.032	20	0.023	0.046	1.215	0.068
Error(section * scenario)	Sphericity Assumed	3.735	-	342	0.011								
	Greenhouse-Geisser	3.735	0.461	157.744	0.024								

Estimated Marginal Means for section

section	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	0.437	0.010	0.417	0.456
2	0.522	0.006	0.511	0.533
3	0.451	0.007	0.437	0.466

Estimated Marginal Means for scenario

scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
0	0.454	0.017	0.420	0.488
1	0.466	0.015	0.436	0.496
2	0.447	0.017	0.414	0.479
3	0.480	0.013	0.455	0.505
4	0.457	0.014	0.429	0.485
5	0.480	0.012	0.457	0.502
6	0.491	0.015	0.462	0.521
7	0.497	0.014	0.470	0.525
8	0.463	0.018	0.429	0.497
9	0.466	0.017	0.433	0.499

Estimated Marginal Means for section * scenario

section	scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	0	0.451	0.016	0.420	0.482
1	1	0.425	0.011	0.403	0.447
1	2	0.359	0.022	0.316	0.402
1	3	0.424	0.011	0.403	0.445
1	4	0.435	0.015	0.406	0.463
1	5	0.422	0.013	0.395	0.448
1	6	0.438	0.012	0.416	0.461
1	7	0.444	0.010	0.425	0.463
1	8	0.449	0.012	0.426	0.473
1	9	0.448	0.010	0.428	0.468
2	0	0.433	0.009	0.416	0.450
2	1	0.414	0.007	0.401	0.428
2	2	0.406	0.004	0.398	0.415
2	3	0.398	0.007	0.384	0.412
2	4	0.419	0.006	0.408	0.430
2	5	0.420	0.008	0.405	0.435
2	6	0.414	0.007	0.400	0.428
2	7	0.413	0.008	0.398	0.428
2	8	0.418	0.007	0.405	0.432
2	9	0.422	0.009	0.404	0.439
3	0	0.447	0.015	0.417	0.477
3	1	0.449	0.018	0.415	0.484
3	2	0.446	0.016	0.414	0.477
3	3	0.447	0.019	0.410	0.485
3	4	0.424	0.025	0.374	0.474
3	5	0.418	0.024	0.370	0.466
3	6	0.453	0.019	0.416	0.490
3	7	0.392	0.018	0.357	0.427
3	8	0.416	0.019	0.379	0.454
3	9	0.410	0.026	0.360	0.461

TESTS OF WITHIN SUBJECTS EFFECTS for Standard Deviation of Accelerator Pedal Position

Source		Type III SS	eps	df	MS	F	Sig.	et2_G	Obs.	SE	95% CI	lambda	Obs. Power
section	Sphericity Assumed	1.820	-	2	0.910	101.912	5.363e-16	0.431	200	0.007	0.014	1072.762	1
	Greenhouse-Geisser	1.820	0.568	1.137	1.601	101.912	5.056e-10	0.431	200	0.007	0.014	1072.762	1
Error(section)	Sphericity Assumed	0.339	-	38	0.009								
	Greenhouse-Geisser	0.339	0.568	21.598	0.016								
scenario	Sphericity Assumed	0.069	-	9	0.008	1.038	0.412	0.016	60	0.011	0.022	3.278	0.179
	Greenhouse-Geisser	0.069	0.779	7.008	0.010	1.038	0.408	0.016	60	0.011	0.022	3.278	0.160
Error(scenario)	Sphericity Assumed	1.265	-	171	0.007								
	Greenhouse-Geisser	1.265	0.779	133.157	0.009								
section * scenario	Sphericity Assumed	0.117	-	18	0.007	1.689	0.039	0.028	20	0.014	0.027	1.778	0.091
	Greenhouse-Geisser	0.117	0.525	9.447	0.012	1.689	0.091	0.028	20	0.014	0.027	1.778	0.079
Error(section * scenario)	Sphericity Assumed	1.317	-	342	0.004								
	Greenhouse-Geisser	1.317	0.525	179.490	0.007								

Estimated Marginal Means for section

section	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	0.212	0.007	0.198	0.225
2	0.225	0.006	0.214	0.235
3	0.102	0.006	0.091	0.113

Estimated Marginal Means for scenario

scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
0	0.173	0.013	0.147	0.199
1	0.195	0.014	0.168	0.222
2	0.175	0.013	0.150	0.200
3	0.182	0.014	0.155	0.208
4	0.190	0.013	0.164	0.216
5	0.176	0.013	0.150	0.202
6	0.156	0.012	0.132	0.180
7	0.173	0.013	0.148	0.198
8	0.187	0.013	0.162	0.212
9	0.189	0.014	0.161	0.216

Estimated Marginal Means for section * scenario

section	scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	0	0.200	0.023	0.156	0.245
1	1	0.251	0.020	0.211	0.290
1	2	0.198	0.020	0.159	0.237
1	3	0.231	0.020	0.191	0.271
1	4	0.228	0.017	0.194	0.262
1	5	0.218	0.023	0.174	0.262
1	6	0.154	0.022	0.110	0.198
1	7	0.181	0.024	0.134	0.229
1	8	0.233	0.018	0.197	0.268
1	9	0.225	0.026	0.175	0.275
2	0	0.216	0.017	0.183	0.248
2	1	0.230	0.020	0.191	0.268
2	2	0.233	0.017	0.200	0.267
2	3	0.225	0.017	0.192	0.259
2	4	0.226	0.021	0.184	0.268
2	5	0.219	0.017	0.185	0.253
2	6	0.214	0.016	0.183	0.246
2	7	0.217	0.019	0.179	0.254
2	8	0.240	0.012	0.216	0.264
2	9	0.226	0.020	0.187	0.266
3	0	0.103	0.020	0.064	0.143
3	1	0.105	0.018	0.069	0.140
3	2	0.093	0.017	0.060	0.126
3	3	0.088	0.017	0.054	0.122
3	4	0.115	0.021	0.074	0.157
3	5	0.092	0.017	0.060	0.124
3	6	0.100	0.018	0.065	0.135
3	7	0.121	0.018	0.085	0.156
3	8	0.088	0.016	0.057	0.119
3	9	0.114	0.020	0.076	0.153

TESTS OF WITHIN SUBJECTS EFFECTS for Mean Steering Wheel Angle

Source		Type III SS	eps	df	MS	F	Sig.	et2_G	Obs.	SE	95% CI	lambda	Obs. Power
section	Sphericity Assumed	0.008	-	2	0.004	0.022	0.978	8.939e-05	200	0.031	0.061	0.235	0.067
	Greenhouse-Geisser	0.008	0.809	1.618	0.005	0.022	0.959	8.939e-05	200	0.031	0.061	0.235	0.065
Error(section)	Sphericity Assumed	7.006	-	38	0.184								
	Greenhouse-Geisser	7.006	0.809	30.739	0.228								
	Huynh-Feldt	7.006	0.809	30.739	0.228								
	Box	7.006	0.500	19	0.369								
scenario	Sphericity Assumed	1.133	-	9	0.126	0.756	0.657	0.012	60	0.053	0.104	2.388	0.138
	Greenhouse-Geisser	1.133	0.681	6.128	0.185	0.756	0.608	0.012	60	0.053	0.104	2.388	0.120
Error(scenario)	Sphericity Assumed	28.472	-	171	0.167								
	Greenhouse-Geisser	28.472	0.681	116.433	0.245								
section * scenario	Sphericity Assumed	1.496	-	18	0.083	0.536	0.940	0.016	20	0.088	0.173	0.564	0.062
	Greenhouse-Geisser	1.496	0.479	8.615	0.174	0.536	0.840	0.016	20	0.088	0.173	0.564	0.058
Error(section * scenario)	Sphericity Assumed	52.999	-	342	0.155								
	Greenhouse-Geisser	52.999	0.479	163.678	0.324								

Estimated Marginal Means for section

section	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	0.011	0.035	-0.057	0.080
2	0.010	0.017	-0.023	0.043
3	0.003	0.030	-0.055	0.061

Estimated Marginal Means for scenario

scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
0	0.086	0.047	-0.006	0.178
1	-0.019	0.061	-0.139	0.101
2	0.009	0.048	-0.085	0.104
3	-0.041	0.048	-0.135	0.052
4	-0.044	0.056	-0.154	0.066
5	-0.007	0.040	-0.086	0.072
6	-0.014	0.051	-0.113	0.085
7	-0.003	0.051	-0.102	0.097
8	0.029	0.050	-0.070	0.128
9	0.083	0.059	-0.032	0.198

Estimated Marginal Means for section * scenario

section	scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	0	0.109	0.104	-0.096	0.313
1	1	-0.002	0.130	-0.257	0.253
1	2	0.093	0.102	-0.107	0.292
1	3	-0.015	0.102	-0.216	0.186
1	4	-0.083	0.115	-0.308	0.142
1	5	-0.045	0.089	-0.220	0.130
1	6	-0.041	0.100	-0.238	0.155
1	7	-0.010	0.108	-0.222	0.202
1	8	0.089	0.107	-0.121	0.300
1	9	0.020	0.148	-0.270	0.311
2	0	0.039	0.039	-0.037	0.115
2	1	0.017	0.045	-0.071	0.105
2	2	-0.003	0.066	-0.132	0.125
2	3	-0.083	0.052	-0.186	0.019
2	4	0.047	0.043	-0.036	0.131
2	5	0.031	0.045	-0.058	0.120
2	6	-0.070	0.055	-0.178	0.037
2	7	-0.029	0.061	-0.148	0.089
2	8	0.071	0.066	-0.058	0.199
2	9	0.077	0.053	-0.027	0.182
3	0	0.110	0.089	-0.063	0.284
3	1	-0.072	0.125	-0.317	0.173
3	2	-0.061	0.079	-0.217	0.094
3	3	-0.026	0.088	-0.198	0.146
3	4	-0.096	0.117	-0.326	0.134
3	5	-0.009	0.070	-0.146	0.129
3	6	0.070	0.101	-0.128	0.268
3	7	0.032	0.094	-0.152	0.216
3	8	-0.072	0.084	-0.237	0.092
3	9	0.153	0.082	-0.009	0.314

TESTS OF WITHIN SUBJECTS EFFECTS for Standard Deviation of Steering Wheel Angle

Source		Type III SS	eps	df	MS	F	Sig.	et2_G	Obs.	SE	95% CI	lambda	Obs. Power
section	Sphericity Assumed	17.946	-	2	8.973	20.896	7.561e-07	0.042	200	0.048	0.094	219.962	1
	Greenhouse-Geisser	17.946	0.713	1.425	12.590	20.896	1.885e-05	0.042	200	0.048	0.094	219.962	1
Error(section)	Sphericity Assumed	16.318	-	38	0.429								
	Greenhouse-Geisser	16.318	0.713	27.084	0.602								
scenario	Sphericity Assumed	12.073	-	9	1.341	1.362	0.209	0.028	60	0.129	0.253	4.302	0.231
	Greenhouse-Geisser	12.073	0.512	4.604	2.622	1.362	0.249	0.028	60	0.129	0.253	4.302	0.167
Error(scenario)	Sphericity Assumed	168.397	-	171	0.985								
	Greenhouse-Geisser	168.397	0.512	87.477	1.925								
section * scenario	Sphericity Assumed	6.864	-	18	0.381	0.842	0.650	0.016	20	0.151	0.296	0.886	0.069
	Greenhouse-Geisser	6.864	0.412	7.420	0.925	0.842	0.560	0.016	20	0.151	0.296	0.886	0.062
Error(section * scenario)	Sphericity Assumed	154.890	-	342	0.453								
	Greenhouse-Geisser	154.890	0.412	140.983	1.099								

Estimated Marginal Means for section

section	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	1.236	0.062	1.115	1.357
2	1.600	0.058	1.486	1.713
3	1.229	0.063	1.105	1.354

Estimated Marginal Means for scenario

scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
0	1.263	0.101	1.065	1.460
1	1.470	0.107	1.260	1.680
2	1.263	0.094	1.078	1.447
3	1.206	0.114	0.984	1.429
4	1.373	0.107	1.164	1.583
5	1.210	0.098	1.018	1.402
6	1.365	0.103	1.162	1.568
7	1.370	0.103	1.167	1.572
8	1.710	0.172	1.372	2.047
9	1.320	0.109	1.107	1.534

Estimated Marginal Means for section * scenario

section	scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	0	1.205	0.153	0.905	1.505
1	1	1.381	0.174	1.040	1.722
1	2	0.962	0.130	0.707	1.218
1	3	0.983	0.183	0.624	1.342
1	4	1.172	0.218	0.744	1.600
1	5	1.197	0.203	0.800	1.594
1	6	1.150	0.156	0.845	1.456
1	7	1.382	0.231	0.930	1.833
1	8	1.613	0.241	1.140	2.085
1	9	1.315	0.227	0.870	1.759
2	0	1.549	0.209	1.139	1.959
2	1	1.651	0.192	1.275	2.027
2	2	1.577	0.188	1.209	1.945
2	3	1.673	0.227	1.228	2.118
2	4	1.573	0.165	1.250	1.896
2	5	1.440	0.159	1.129	1.751
2	6	1.686	0.196	1.301	2.070
2	7	1.627	0.161	1.312	1.942
2	8	1.749	0.193	1.371	2.127
2	9	1.471	0.160	1.157	1.785
3	0	1.035	0.142	0.756	1.314
3	1	1.378	0.192	1.001	1.755
3	2	1.248	0.142	0.969	1.527
3	3	0.963	0.134	0.701	1.225
3	4	1.375	0.166	1.050	1.700
3	5	0.992	0.134	0.730	1.254
3	6	1.260	0.169	0.928	1.591
3	7	1.100	0.115	0.875	1.325
3	8	1.768	0.425	0.936	2.600
3	9	1.176	0.177	0.829	1.522

TESTS OF WITHIN SUBJECTS EFFECTS for Mean Vehicle Speed

Source		Type III SS	eps	df	MS	F	Sig.	et2_G	Obs.	SE	95% CI	lambda	Obs. Power
section	Sphericity Assumed	38528.800	-	2	19264.400	151.432	7.886e-19	1.445	200	0.824	1.615	1594.021	1
	Greenhouse-Geisser	38528.800	0.526	1.053	36596.066	151.432	6.117e-11	1.445	200	0.824	1.615	1594.021	1
Error(section)	Sphericity Assumed	4834.164	-	38	127.215								
	Greenhouse-Geisser	4834.164	0.526	20.003	241.667								
scenario	Sphericity Assumed	837.013	-	9	93.001	2.362	0.015	0.031	60	0.816	1.599	7.458	0.403
	Greenhouse-Geisser	837.013	0.430	3.869	216.336	2.362	0.063	0.031	60	0.816	1.599	7.458	0.249
Error(scenario)	Sphericity Assumed	6733.724	-	171	39.379								
	Greenhouse-Geisser	6733.724	0.430	73.512	91.600								
section * scenario	Sphericity Assumed	334.844	-	18	18.602	0.753	0.755	0.013	20	1.115	2.186	0.793	0.067
	Greenhouse-Geisser	334.844	0.400	7.200	46.506	0.753	0.631	0.013	20	1.115	2.186	0.793	0.061
Error(section * scenario)	Sphericity Assumed	8449.741	-	342	24.707								
	Greenhouse-Geisser	8449.741	0.400	136.801	61.766								

Estimated Marginal Means for section

section	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	50.411	0.425	49.577	51.244
2	69.254	0.501	68.272	70.235
3	64.594	0.517	63.580	65.608

Estimated Marginal Means for scenario

scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
0	61.821	1.281	59.309	64.332
1	61.692	1.508	58.736	64.648
2	58.656	1.534	55.650	61.662
3	61.949	1.357	59.290	64.608
4	60.831	1.198	58.483	63.178
5	61.118	1.185	58.796	63.439
6	63.173	1.198	60.824	65.522
7	62.815	1.361	60.148	65.482
8	60.855	1.507	57.901	63.809
9	61.285	1.416	58.509	64.061

Estimated Marginal Means for section * scenario

section	scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	0	51.489	1.288	48.964	54.014
1	1	48.716	1.291	46.185	51.247
1	2	47.479	1.483	44.573	50.385
1	3	50.892	1.010	48.912	52.871
1	4	49.804	1.079	47.690	51.918
1	5	50.340	0.957	48.465	52.216
1	6	53.725	1.341	51.098	56.353
1	7	52.287	1.523	49.303	55.272
1	8	49.019	1.583	45.915	52.122
1	9	50.357	1.455	47.505	53.209
2	0	68.507	1.526	65.516	71.498
2	1	70.737	1.784	67.240	74.234
2	2	66.749	1.842	63.139	70.359
2	3	69.048	1.698	65.719	72.377
2	4	68.614	1.164	66.332	70.896
2	5	69.139	1.220	66.747	71.530
2	6	70.300	1.509	67.341	73.258
2	7	70.007	1.712	66.650	73.363
2	8	70.028	1.573	66.945	73.111
2	9	69.407	1.830	65.820	72.995
3	0	65.467	1.624	62.285	68.649
3	1	65.623	1.534	62.616	68.631
3	2	61.740	2.407	57.021	66.458
3	3	65.908	1.825	62.331	69.484
3	4	64.074	0.838	62.432	65.717
3	5	63.874	0.878	62.154	65.594
3	6	65.494	1.283	62.979	68.010
3	7	66.152	1.690	62.839	69.464
3	8	63.518	2.000	59.597	67.438
3	9	64.091	1.746	60.669	67.512

TESTS OF WITHIN SUBJECTS EFFECTS for Standard Deviation of Vehicle Speed

Source		Type III SS	eps	df	MS	F	Sig.	et2_G	Obs.	SE	95% CI	lambda	Obs. Power
section	Sphericity Assumed	3617.746	-	2	1808.873	84.455	1.038e-14	0.706	200	0.338	0.662	888.997	1
	Greenhouse-Geisser	3617.746	0.592	1.185	3053.116	84.455	1.369e-09	0.706	200	0.338	0.662	888.997	1
Error(section)	Sphericity Assumed	813.894	-	38	21.418								
	Greenhouse-Geisser	813.894	0.592	22.514	36.151								
scenario	Sphericity Assumed	164.671	-	9	18.297	2.375	0.015	0.032	60	0.361	0.707	7.499	0.405
	Greenhouse-Geisser	164.671	0.660	5.941	27.718	2.375	0.034	0.032	60	0.361	0.707	7.499	0.317
Error(scenario)	Sphericity Assumed	1317.591	-	171	7.705								
	Greenhouse-Geisser	1317.591	0.660	112.876	11.673								
section * scenario	Sphericity Assumed	155.760	-	18	8.653	1.287	0.193	0.030	20	0.582	1.140	1.355	0.080
	Greenhouse-Geisser	155.760	0.429	7.723	20.168	1.287	0.256	0.030	20	0.582	1.140	1.355	0.070
Error(section * scenario)	Sphericity Assumed	2298.800	-	342	6.722								
	Greenhouse-Geisser	2298.800	0.429	146.742	15.666								

Estimated Marginal Means for section

section	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	5.548	0.282	4.996	6.100
2	7.425	0.224	6.987	7.864
3	1.538	0.085	1.371	1.705

Estimated Marginal Means for scenario

scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
0	4.456	0.448	3.579	5.334
1	5.684	0.569	4.569	6.798
2	5.442	0.553	4.357	6.526
3	4.270	0.466	3.356	5.184
4	4.494	0.462	3.589	5.399
5	4.729	0.445	3.855	5.602
6	4.191	0.451	3.306	5.075
7	4.771	0.490	3.811	5.731
8	5.629	0.588	4.476	6.782
9	4.706	0.514	3.699	5.713

Estimated Marginal Means for section * scenario

section	scenario	Mean	Std. Error	95% Lower Bound	95% Upper Bound
1	0	4.996	0.767	3.492	6.500
1	1	7.821	0.896	6.064	9.577
1	2	5.500	0.812	3.909	7.091
1	3	4.387	0.778	2.863	5.911
1	4	4.851	0.865	3.155	6.546
1	5	5.808	0.796	4.248	7.368
1	6	4.020	0.768	2.515	5.525
1	7	5.437	0.836	3.798	7.076
1	8	6.882	1.094	4.739	9.026
1	9	5.781	1.088	3.649	7.912
2	0	7.005	0.631	5.769	8.242
2	1	7.861	0.840	6.215	9.507
2	2	8.866	0.731	7.434	10.298
2	3	7.021	0.734	5.583	8.460
2	4	7.265	0.540	6.207	8.323
2	5	6.905	0.568	5.791	8.019
2	6	6.956	0.721	5.543	8.370
2	7	7.593	0.658	6.304	8.883
2	8	7.997	0.940	6.154	9.840
2	9	6.782	0.642	5.525	8.040
3	0	1.368	0.146	1.083	1.654
3	1	1.369	0.181	1.014	1.725
3	2	1.959	0.634	0.716	3.202
3	3	1.401	0.225	0.960	1.843
3	4	1.367	0.147	1.078	1.656
3	5	1.473	0.153	1.173	1.773
3	6	1.596	0.169	1.265	1.927
3	7	1.283	0.138	1.012	1.554
3	8	2.008	0.279	1.462	2.554
3	9	1.555	0.235	1.095	2.015